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WEEKLY 18 November 2017

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SEAN GALLUP/GETTY

Fertile territory for change

Falling sperm counts are a chance to redress an imbalance

THE plot of P.D. James's dystopian novel *The Children Of Men* revolves around a provocative thought experiment: what would happen if humans stopped being able to reproduce? In the story, set in 2021, no child has been born in the past 25 years and *Homo sapiens* is heading for extinction. With no future to plan for, society is spiralling into the ultimate fin-de-siècle decadence.

By the time 2021 comes around for real, life may be starting to imitate art. In July, Israeli scientists reported that sperm counts in developed countries have declined by more than half in the past 40 years and continue to fall by about 1.6 per cent a year. "Shocking" and "a wake-up call" were two of the responses from other scientists.

The cause of the fertility crisis in *The Children Of Men* was a global disease. The cause of ours is not known (see page 28). To say that we urgently need some research into it is not an exaggeration. We are almost certainly not heading for a total collapse of male fertility, but sperm counts are approaching dangerously low levels. Around one in 10 couples already

experience fertility problems. And yet our scientific understanding of male infertility remains rudimentary, with some researchers complaining that they struggle to get funding to do the long-term, large-scale studies needed to get to the bottom of the problem.

For many women, the news that men are suddenly in the spotlight will feel like a welcome role reversal. Difficulty conceiving has long been treated as a "women thing" by society and medicine alike. In the UK, for example,

"Difficulty conceiving has long been treated as a 'women thing' by society and medicine alike"

even if a couple's fertility problems lie with the man, it is still the woman's GP who makes the referral; the man isn't even considered to be the patient. Men are also largely exempt from the social pressure of the ticking body clock, even though recent research suggests that this is dangerously complacent.

If the male fertility crisis has a silver lining, it is an opportunity to discuss and redress these long-

standing gender inequalities.

Would-be fathers need to be part of this process. In the UK, women's reproductive health needs are addressed by the Royal College of Obstetricians and Gynaecologists. There is no equivalent body for men. Men could legitimately argue that this represents an uncommon case in which they are subject to gender discrimination.

But this hand must not be overplayed. Discrimination largely runs the usual way, with women on the receiving end. The way we treat infertility resembles the patriarchy in Margaret Atwood's *The Handmaid's Tale*, another dystopian novel with an infertility crisis at its heart, where failure to conceive is routinely blamed entirely on females.

In recent weeks the world has had to confront some sobering realities about women's rights. In too many walks of life, women are still not treated as equals: consider the sexual abuse scandals rocking Hollywood, the UK parliament and elsewhere. The science and medicine of infertility are not mired in similar scandal, but need to examine their prejudices nonetheless. ■



Emissions are rising again

IF WE don't do more to limit emissions of greenhouse gases soon, we will be unable to stop the world warming by 2°C. Carbon emissions from fossil fuels and industry are set to rise this year, after three years of stasis.

"This is really not good news," says Corinne Le Quéré of the Tyndall Centre for Climate Change Research in the UK. Despite the 2015 Paris Agreement, we are doing too little to halt climate change. Yet there is consensus on what must be done: put a meaningful price on carbon.

"A carbon price is absolutely essential," economist Nicholas Stern told a London meeting organised by the Task Force on Climate-related Financial Disclosures last month. "We may be on a path to 3°C. The risks are enormous." The biggest obstacle to investment in clean growth is

governments' failure to pursue clear and predictable policies, he said. That includes a well-designed carbon price.

The European Union has a carbon trading scheme, but its carbon price is low and erratic, which doesn't drive cuts. The scheme has been close to useless, says Wendel Trio of Climate Action Network Europe, adding that a new round of reforms won't fix this.

Businesses must know "the price of carbon is going to be high and that the price will increase", says Le Quéré.

Her team previously found steady emissions from 2014 to 2016 from fossil fuels and industry, despite economic growth. But in 2017, these emissions are projected to rise 2 per cent to 37 gigatonnes of carbon dioxide (*Environmental Research Letters*, doi.org/cf7n). Extra CO₂ has been emitted by burning rainforests

to clear land (pictured), so total emissions may be 41 gigatonnes.

The growth in fossil fuel emissions is largely due to China, which is behind a third of all CO₂ emissions, says Glen Peters of the Center for International Climate Research, Norway. Emissions flattened when China's boom ended. Now its growth is picking up again.

To halt the growth in atmospheric CO₂, emissions must stop. Limiting warming to 2°C requires emissions to fall more than 5 per cent per year.

"Once we get above about 2°C of warming relative to the preindustrial - and we're not that far away from it now - we see some of the worst and potentially irreversible changes in climate," says Michael Mann of Penn State University. "We are talking about a fundamental threat to our way of life."

NHS plan backfires

REORGANISING the National Health Service in England has failed to increase the amount of care taking place in the community.

The health service changed radically in England in 2013, when two-thirds of the NHS budget was transferred to family doctors. The hope was that more people could be treated relatively cheaply locally, rather going for assessment or treatment at hospitals.

But a study has found that the rate of people going into hospital between 2013 and 2015 has remained static. By the end of 2015, the number of referrals to specialists had increased by 19 per cent. Rates of hospitalisation

"The idea was to shift more care into the community, but our findings suggest that's not been happening"

and referrals were unaltered in Scotland, where no reforms took place (*PLOS Medicine*, DOI: 10.1371/journal.pmed.1002427).

"It's hard to say whether the policy as a whole is a failure," says James Lopez Bernal of the London School of Hygiene and Tropical Medicine. "But we know that the idea was to shift more care into the community, and our findings suggest that's not been happening."

Digital drug

A PILL that can tell your doctor if you've taken your medication or not has been approved for the first time.

The drug is an antipsychotic medicine for people with schizophrenia or bipolar disorder. Each pill contains an electronic sensor that is activated upon contact with stomach fluid, sending a message to a patch worn by the patient. This patch registers when the pill was taken on the person's smartphone.

The digital pill, named Abilify MyCite, was approved this week by the US Food and Drug Administration. If a patient consents, the system can remotely inform others when they take the drug, enabling their family, carers or doctor to check if they are sticking to the regime.

However, the FDA has warned that it isn't yet known whether such a system will make patients more likely to take their medication. The agency has also said that family doctors must ensure patients fully consent to take the pill, wear the patch and use the associated phone app.

Satellite nation

THE Space Kingdom of Asgardia has launched its first satellite.

This so-called "virtual nation" is the pet project of Russian scientist and billionaire Igor Ashurbeyli. He proposed it should exist in space to avoid the control of nations on Earth.

The Asgardia-1 satellite, which is about the size of a loaf of bread, launched on 12 November and holds half a terabyte of data, including Asgardia's constitution, its national symbols and data from its 115,000 citizens. It was launched aboard a Cygnus spacecraft.

The Cygnus craft will dock with the International Space Station on 14 November to perform its primary mission of delivering supplies to the astronauts there. After about a month, it will undock and fly higher above Earth, where it will release Asgardia's satellite into orbit. While Ashurbeyli has plans to convince the UN to recognise Asgardia as a sovereign nation and someday build colonies in space, it isn't currently recognised by any country on Earth.

Time will tell whether the Space Kingdom of Asgardia becomes the first space-based nation or whether it will remain simply an orbiting external hard drive.

Qubits for hire

IBM has announced a leap forward in quantum computing. The company unveiled two new quantum computers, one with 20 quantum bits, or qubits, which IBM says will be available at the end of the year, and a 50-qubit prototype.

IBM is racing Google and several other firms to establish quantum supremacy by outperforming classical computers with quantum machines. Right now, classical computers can simulate 56 qubits.

Both of these new quantum

computers can perform quantum calculations for 90 microseconds, longer than any other quantum computer to date. The 20-qubit computer will be available to IBM's clients at the end of the year for running quantum algorithms

"Both computers can do quantum calculations for 90 microseconds, longer than any other to date"

and simulations. The 50-qubit prototype is not yet ready for widespread use, but IBM says it will form the basis of their future quantum computers.

Earthquake strikes Iran and Iraq

AN EARTHQUAKE has hit the border of Iran and Iraq, killing more than 500 people and injuring almost 8000.

Centred 31 kilometres from Halabja in east Iraq, the magnitude-7.3 quake was felt as far afield as the Mediterranean. It was caused by the Arabian plate moving north and hitting the neighbouring Eurasian plate at an angle. "The two plates converge along a north-west-striking plate boundary... driving the uplift of the Zagros mountains in Iran," according to an assessment by the US Geological Survey.

The long collision zone creates quakes that slip over a large area. "The seismic energy radiates out, so you can be quite a distance from the epicentre and still feel it," says Roger

Musson at the British Geological Survey. What's more, many additional faults also meet around the point of collision, he says. "What's happening is a broad collision zone across the Zagros mountains, where a number of faults are parallel with the Iran-Iraq border."

Monday's quake may be the largest possible on that plate boundary, says Musson. "The limit is probably 7.2 to 7.3." The rocks under the Zagros mountains include layers of softer rock, which prevent the full force of larger quakes reaching the surface.

As *New Scientist* went to press, seismologists were warning that severe aftershocks could follow. "A magnitude-6 quake would not be totally surprising," says Musson.



As big as it gets

AHMAD HALABISAZ/XINHUA NEWS AGENCY/CIPA IMAGES

60 SECONDS

Face ID unlocked?

Hackers say they have already managed to beat the Face ID system on Apple's iPhone X. Just a week after its launch, security firm Bkav released a video that purports to show the phone unlocking when presented with a 3D-printed mask. Face ID works by creating a detailed map of the user's face - and Apple said that iPhone X cannot be fooled by masks or make-up.

Liver overdose test

A blood test can spot if people who have overdosed on paracetamol are at risk of liver problems. The test detects three molecules linked to liver damage, and may help clinicians decide how long a patient should stay in hospital (*Lancet Gastroenterology & Hepatology*, doi.org/cf8c).

Rising storms

Cyclones are rare in the Arabian Sea, but three hurricane-strength storms struck the region in 2014 and 2015. Now it seems climate change may be partly responsible: 64 per cent of the increased risk of hurricanes in the area in 2015 can be attributed to climate change (*Nature Climate Change*, doi.org/cf7s).

Diet for longer life

A study of 54 trials involving more than 30,000 adults has found that weight-loss diets - particularly those low in fat - reduce the risk of early death by 18 per cent in people with obesity. Previous studies have also found that such diets can prevent type 2 diabetes (*BMJ*, DOI: 10.1136/bmj.j4849).

First signs of wine

The oldest evidence of wine-making has been uncovered at a site south of Tbilisi in Georgia. Earthenware jars from 8000 years ago were found to contain traces of chemicals found in wine, and some also carried images of grape clusters (*PNAS*, doi.org/cf7t). Previously, the oldest evidence of viticulture came from Iran 7000 years ago.

Brain implant boosts memory

A device that mimics the electrical signals of learning ups brain power

Jessica Hamzelou

ELECTRICAL shocks that simulate the patterns seen in the brain when you are learning have enhanced human memory for the first time, boosting performance on tests by up to 30 per cent. A similar approach may work for enhancing other brain skills, such as vision or movement, says the team behind the work.

"We are writing the neural code to enhance memory function," says Dong Song of the University of Southern California, who presented the findings at the Society for Neuroscience meeting in Washington DC this week. "This has never been done before."

The device mimics the brain signals associated with learning and memory, stimulating similar patterns of brain activity in the hippocampus via electrodes. Song and his team implanted their device in 20 volunteers who were already having electrodes placed in their brains to treat epilepsy.

First, the team used the device to collect data on patterns of activity in the brain when the volunteers were doing a memory test. It involved trying to remember which unusual, blobby shapes they had been shown 5 to 10 seconds before. This test measures short-term memory, and people normally score around 80 per cent on this task.

Rerouting memory

The volunteers also did a more difficult version of the test, in which they had to remember images they had seen between 10 and 40 minutes before. This measures working memory – the things we keep at the front of our minds while making decisions, for example.

The team used the data to work out the patterns of brain activity associated with each person's best memory performances. The group then made the device electrically stimulate similar brain activity in the volunteers while they did more tests.

A third of the time, the device stimulated the participants' brains in a way the team thought would be helpful. Another third of the time, it stimulated the brain with random patterns of electricity. For the remaining third of the time, it didn't stimulate the brain at all.

Memory performance improved by about 15 per cent in the short-term memory test and around 25 per cent in the working-

memory test when the correct stimulation pattern was used, compared with no stimulation at all, says Song. Some improved by 30 per cent. Random stimulation worsened performance. It is the first time a device like this has been found to enhance an aspect of human cognition, says Song.

"It's exciting, pioneering work," says Sinead Mullally at Newcastle University, UK. "It is obviously a very early demonstration. But these are exciting results that are potentially quite important."

Song hopes the device could

help people with Alzheimer's and other dementias. He thinks it could bypass the damage caused by cell death in the hippocampus in these disorders. "That should reinstate and restore cognitive function."

The hippocampus is vulnerable to damage, whether from injuries or infections, says Mullally. Theoretically, a device that bypasses regions of the hippocampus could provide a much-needed treatment, although the risks would have to be considered first, she says.

Chris Bird of the University of Sussex, UK, agrees that such a device may be useful for treating medical conditions. But he says the prosthesis wouldn't be able to fully replace the hippocampus. "The hippocampus is quite a large structure and they are only recording from a very small area," he says. "It's like dipping a bucket in a swimming pool."

The team is now working on ways to enhance other brain functions. "The approach is very general," says Song. "If you can improve the input/output of one brain region, you could apply it to other brain regions."

Good candidates for this are skills localised to particular parts of the brain, such as sensation of the outside world, vision and how we move. Enhancing these might improve a person's hand-eye coordination, say. Cognitive functions like intelligence, however, involve many brain regions working together so wouldn't make good targets.

The team is also investigating whether the device can implant false memories. "For example, if we show a picture of a dog, is there a pattern associated with the dog that we can use to create a false memory of the dog?" says Song. ■

"We are writing the neural code to enhance memory function. This has never been done before"



Need a brain boost?

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Monkey flosses its teeth with a bird feather

MONKEYS living on an island have learned to use a variety of tools and techniques to obtain food – and to floss their teeth afterwards.

Honnnavalli Kumara at the Sálím Ali Centre for Ornithology and Natural History in Coimbatore, India, and colleagues followed 20 Nicobar long-tailed macaques (*Macaca fascicularis umbrosus*) on Great Nicobar Island in the Indian Ocean.

Many of the macaques' favoured foods are thorny, slimy or mucky. To get rid of these inedible coatings, the macaques either wash the food in puddles or wrap it in leaves and rub them clean. They also wrap leaves around foods to make them easier to hold (*Primates*, doi.org/cf63).

The macaques eat coconuts too, plucking them from trees by twisting them around or using their teeth to cut them off. If a coconut is tender, the macaques dehusk it with their teeth. But if it is ripe, they have to crack its shell. To do so, they take it to a hard surface like a rock, and pound it.

It's not just tool use. The macaques were seen beating bushes with their hands to disturb hidden insects, catching those that fly out.

After eating, adult and sub-adult macaques clean their teeth. Nine were seen holding a fine fibre between their teeth and pulling at it. These included a tree needle, a bird feather, a blade of grass, a coconut fibre, a nylon thread and a metal wire.

They are the third monkeys seen flossing their teeth. Japanese macaques use their fur and Thailand's long-tailed macaques use human hair.

Most of the behaviours have been seen in other monkeys, says Dorothy Fragaszy at the University of Georgia, Athens. "The newest element, to me, is 'bush-beating' to flush insect prey."

Macaques adapt well to human-dominated landscapes, says Michael Gumert at the Nanyang Technological University, Singapore. "They are the king of generalists... about as adaptable as we are." Richa Malhotra ■



Surprisingly human

Ancient skull from China may rewrite our origins

THE origins of our species might need a rethink. An ancient skull from China is eerily similar to the oldest known fossils of our species – found in Morocco, some 10,000 kilometres to the west. The skull hints that modern humans aren't solely descended from African ancestors, as is generally thought.

Most anthropologists believe that our species arose in Africa 200,000 years ago. Our genes show we are all descended from a single population that left Africa within the last 120,000 years and went global. This African group is the source of all human genes, barring a few gained by mating with species like Neanderthals.

However, the Dali skull may not fit the story. Found in China in 1978, it still has its face and brain case. A study published in April showed it is 260,000 years old.

When it was described, people assumed it was a *Homo erectus*. These hominins arrived in South-East Asia 1.8 million years ago and vanished 140,000 years ago. That fits the standard story.

But in 1981, Xinzhi Wu at the Chinese Academy of Sciences in Beijing argued that the Dali skull's face looked a lot like our species, *Homo sapiens*. This implied that *H. erectus* in east Asia contributed to the origin of *H. sapiens* and that some of the DNA in living humans came from Asian *H. erectus*.

Today, many researchers reject this idea, as it contradicts the out-of-Africa model. So Wu and Sheela

"Gene flow could have been multidirectional, so some traits seen in Africa could have originated in Asia"

Athreya at Texas A&M University in College Station compared the Dali skull with other hominins, including *H. erectus* and *H. sapiens*. They found it is similar to two *H. sapiens* skulls from Jebel Irhoud in Morocco (*American Journal of Physical Anthropology*, doi.org/cf7k). "I really wasn't expecting that," says Athreya.

This year, researchers at Jebel Irhoud found bits of a third *H. sapiens* skull and dated the

fossils to about 315,000 years ago. This pushed back our species' origin by 115,000 years. Like the Dali skull, the Jebel Irhoud skulls have *H. sapiens*-like faces but their brain cases look more primitive.

The Moroccan skulls fit with the idea that *H. sapiens* evolved solely in Africa from hominins living there. But Athreya says the Dali skull suggests something else.

It's possible, she says, that the hominins in Africa weren't cut off from those in Eurasia. The small-scale movements of individuals – like young adults leaving a family group and joining a neighbouring one – could have allowed genes to flow across Africa and Eurasia. That means the genetic features of *H. sapiens* that appeared in Morocco 315,000 years ago could have cropped up in individuals – like the Dali skull's owner – in China 260,000 years ago.

There is another implication. "I think gene flow could have been multidirectional, so some of the traits seen in Europe or Africa could have originated in Asia," says Athreya. That means features associated with *H. sapiens* may have evolved in east Asia, and been carried to Africa. If so, our origins are not solely African.

The alternatives are that *H. sapiens* left Africa far earlier than we thought, reaching China by 260,000 years ago, which contradicts the genetic evidence, or that Asian *H. erectus* separately evolved some of the traits of modern humans, but these "proto-humans" left no descendants.

Far more data is needed, says John Hawks at the University of Wisconsin-Madison. But he is open to the idea that the Dali skull is from the population that became our species. "We are talking about a multiregional population, connected recurrently by migration and genetic exchanges."

The evidence is weak, says Chris Stringer at the Natural History Museum in London. "I'm open to Asian-African connections at this time, but western Asia-Africa, not further afield." Colin Barras ■

Porpoise aims its sonar by twisting physics laws

PORPOISES have the combination of acoustic controls built into their heads to thank for their ability to focus a directed beam of sonar on prey. The bone, air and tissues in their skulls behave like a metamaterial, a material designed to defy the normal laws of physics. These sea mammals can convert non-directional sound waves into a narrow laser of sound.

Like dolphins, porpoises use echolocation to detect prey under water up to 30 metres away. To do this, they emit high frequency clicks in a focused beam in front of their faces, controlling the direction of the beam without moving their heads. They can also widen the beam as they approach their target, helping them catch fish that try to escape.

How they focus the beam is something of a mystery, particularly as the structures that produce the sound – called phonic lips – are smaller than the wavelength of the clicks they produce. This should result in the waveform being spread out instead of targeted. A large fatty

organ in the front of the head, called the melon, appears to be important, but the details of the role it plays have been unclear.

To investigate, Yu Zhang of Xiamen University in China and his colleagues have carried out computed tomography (CT) scans of a finless porpoise to measure the acoustic properties of different tissues in its head.

Their work will be published in *Physical Review Applied*. They have also gathered field recordings of porpoise signals and built a mathematical model to simulate how porpoises generate and control their sound beams.

“This kind of animal is difficult to do experiments with,” says Zhang. “CT and computer simulations help us to see what happens within the porpoise’s head.” The key, it turns out, is how the melon, the skull and air sacs in the head work together, forcing the sound wave in a single

direction. Each of these parts of a porpoise’s head reflects, refracts and scatters sound in different ways, and sound travels through each of them at different speeds.

A porpoise can widen its beam of sound by compressing its melon with its facial muscles. That allows it to keep a fish in its line of “sight” while chasing it.

“The biosonar system of the porpoise uses different principles than what we learn in textbooks,” says co-author Wenwu Cao of Pennsylvania State University. He says it hints at a new way to design small accurate sonar systems for locating targets in the ocean.

It might also help us make metamaterials with an atomic structure that can combine properties like these. This might be particularly useful for the design of transducers – the parts of sonar systems that convert electrical pulses into sound waves – says Keith Brown at Heriot-Watt University in Edinburgh, UK.

At the moment, “if you want to build a low frequency transducer with high directivity, it has to be very big”, he says. “Making metamaterials that look at how the dolphins and porpoises do things may allow smaller transducers.” **Sam Wong ■**



STEPHEN FRANK COLLECTION / ALAMY STOCK PHOTO

It's all in their heads

A plan to seed life throughout the cosmos

OUR galaxy may contain billions of habitable but lifeless worlds. Should we try to change that? Claudius Gros at Goethe University Frankfurt, Germany, thinks so. He believes in directed panspermia: deliberately seeding life throughout the cosmos. To do so, he proposes we use a laser propulsion system that may not be technically out of reach.

Breakthrough Starshot is an ambitious existing proposal to use giant lasers and light sails to send tiny probes to Alpha Centauri. The goal is to take pictures of this star. But these

systems could also deliver much larger payloads, says Gros.

With no way to stop, Starshot’s single gram craft would zoom past its target just hours after arrival. To slow his probe down and put it into orbit, Gros suggests using magnetised sails to transfer its momentum to the interstellar particles hitting them once the lasers are no longer providing propulsion.

Deep space can be near empty, perhaps containing just one atom per cubic centimetre, so vast sails would be needed to make this work. With the latest high-temperature superconducting wires – which lose barely any energy even at well above absolute zero – Gros calculates it is possible to make magnetised sails big enough to slow down a heavier craft.

Potential targets include planets orbiting TRAPPIST-1, a red dwarf star just 40 light years away. These may have oxygen-rich atmospheres that would make them habitable today, but could have prevented life forming initially by destroying organic chemicals. “Our galaxy may contain billions of sterile, but habitable worlds,” says Gros.

He proposes using autonomous toolkits for life that would grow genes and cells from chemical ingredients on arrival. Gros estimates that a 1.5-tonne craft carrying sails 50-kilometres wide could reach TRAPPIST-1 in

12,000 years if propelled by Starshot’s lasers (*Journal of Physics Communications*, doi.org/cf7h).

Chi Thiem Hoang at the Korea Astronomy and Space Science Institute wonders if the superconducting wire that would form the proposed sails could survive collisions with interstellar dust, but he agrees that the Starshot setup could technically launch such a mission. “I think that it would be interesting to use the proposed system to spread some form of life,” he says.

Jeff Kuhn, a physicist at the University of Hawaii who advises Starshot, likes the paper, but worries that gaining support and funding for a mission that takes 12,000 years might be harder than actually building and launching one. **James Romero ■**

“A craft with 50-kilometre-wide sails could reach the red dwarf TRAPPIST-1 in 12,000 years”

Tinfoil hat keeps your Wi-Fi at home

Wi-Fi signals can sometimes struggle to reach every room in a home – and yet be easy pickings for anyone passing by outside. Now there may be a quick and relatively easy solution.

Researchers at Dartmouth College in New Hampshire have developed customised reflectors that sit on routers and precisely control the shape of the Wi-Fi signals they emit.

It is already possible to boost a weak signal, but the new tech also allows the signal to be deadened in areas where you don't want it, such as near windows, to help prevent anyone outside snooping on your network.

"We can make it hard for others to get connected to your access point," says Xia Zhou, who led the research.

Zhou and her team designed an algorithm that can calculate the ideal shape of a reflector needed to change the Wi-Fi signal coverage to someone's specifications.

A user can then specify exactly where they want to boost and lower their wireless coverage. For example, they might want the Wi-Fi in their kitchen to be stronger, but to reduce the signal bleeding out of their home onto the road. "We can bounce the signals in a way that mitigates the impact of building insulation, partitions and interior layout," Zhou says. The resulting reflector can then be 3D printed at home.

Zhou's kitchen-foil wrapped reflectors were able to boost a Wi-Fi signal by up to 55 per cent in areas where it was desired – and reduce it by up to 63 per cent where it wasn't.

The team is now trying to develop a user-friendly interface to make it easier for people to upload models of their home and shape their Wi-Fi signal how they want.

But keep that password protection on your router. "The only way to secure a Wi-Fi connection with any reliability is to encrypt it," says Alan Woodward, a computer security expert at the University of Surrey, UK. Richard Gray ■



Social stress ups inflammation

How bullying can lead to depression

Andy Coghlan

EXPERIENCES like bullying make the blood-brain barrier leaky, leading to brain inflammation and leaving you vulnerable to depression, according to studies of human brains and mice.

Anything that threatens your sense of worth is a type of social stress – be it bullying, body-image issues, social anxiety or extreme shyness. To see how such stresses affect mood, Scott Russo of the Icahn School of Medicine at Mount Sinai, New York, and his team exposed 24 small, subordinate mice to larger, dominant mice for 10 minutes every day, for 10 days. Ten of the mice coped well, but 14 became socially withdrawn and more timid.

Comparing blood, DNA and tissue samples from the small mice and control mice suggests that social stress changes mood in three stages. First, the stress kicks off inflammation in the bloodstream. This weakens the blood-brain barrier, which normally protects the brain,

making it more likely to let substances in.

This enables large molecules like inflammatory substance interleukin-6 and aggressive white blood cells called monocytes to pass into the brain. Here they seem to disrupt signalling in the nucleus accumbens, which helps evaluate threats and rewards. This is the first study to link social stress to

"This is the first time social stress has been linked to the blood-brain barrier and depressive behaviour"

blood-brain barrier dysfunction and depression-related behaviour, says Russo.

In stressed mice, up to 30 per cent of vessels lining the blood-brain barrier showed signs of breaches in the nucleus accumbens. This seems to be caused by changes in gene activity – in stressed mice, genes in this brain area produced 40 per cent less of a protein called claudin-5, which

usually secures the integrity of the blood-brain barrier.

When the team examined post-mortem brain tissue from 39 people who'd had depression, and 24 people who hadn't, they saw that levels of claudin-5 in the nucleus accumbens of many of those who'd had depression were about 50 per cent lower (*Nature Neuroscience*, doi.org/cf7q).

"The study cements the central role of inflammation in the genesis of mood disorders," says Michael Berk at the University of Melbourne in Australia.

Russo says the study suggests new avenues for treating depression. One option would be to use an antibody, sirukumab, to remove interleukin-6 from the blood, so that it can't reach the brain. This approach is already being tested in people with depression.

Other strategies may work too. One could be to shore up the blood-brain barrier, making it less likely to let inflammatory molecules through, or reducing the level of monocytes in the blood. If approaches like this work, they may help prevent depression developing in people who are in difficult circumstances – such as a hostile work environment or a stressful family situation ■

Giant coconut crab stalks and kills bird

Jake Buehler

A COCONUT crab has been spotted hunting and devouring a seabird. It is the first time coconut crabs have been seen actively hunting large animals, and suggests they rule their island homes.

Coconut crabs (*Birgus latro*), or robber crabs, are imposing. They can weigh up to 4 kilograms, as much as a house cat, and sport legs that span almost a metre. This makes them the largest invertebrates – animals without backbones – on land. The crabs live on coral atolls in the tropical Indian and Pacific oceans.

They are renowned for their tree-climbing abilities and taste for coconuts, which they crack with their powerful claws. They do sometimes eat meat, but until now it was thought they only got it by opportunistic scavenging.

Between January and March 2016, Mark Laidre of Dartmouth College in New Hampshire visited the Chagos Archipelago, a remote series of atolls in the Indian Ocean. Chagos is ideal for studying coconut crabs: it is in pristine condition, is surrounded by one of the largest marine

reserves on earth and has lots of coconut crabs, making them easier to find and observe.

One night, Laidre filmed a coconut crab slowly climb a tree. The crab inched towards a common seabird called a red-footed booby (*Sula sula*), which was asleep in a nest near ground level. It then lunged with a claw, pinching and breaking the bone in one of the bird's wings and making it tumble out of the tree.

Breaking a bird's wing is easy

for a coconut crab, says Shin-ichi Oka at the Okinawa Churashima Foundation Research Center in Japan. In 2016, he found the crabs' claws pinch with a force of up to 3300 newtons, stronger than any other crustacean and comparable to the bite force of a big predator like a lion. "The claws of coconut crabs can generate a force 80 to 100 times the mass of their body," says Oka. "The crab in the video seems to be about 2 kilograms, so it would be able to easily break the bird's bones."

After the first attack, the crab descended and followed the bird, breaking the other wing with its claws. "At that point, when both its wings were broken and it was on the ground, it couldn't

go anywhere," says Laidre.

Before long, five other coconut crabs arrived on the scene, maybe lured by the commotion and scent of blood. They proceeded to tear the bird apart and eat it (*Frontiers in Ecology and the Environment*, doi.org/cf5q). "It was pretty gruesome," says Laidre.

If enough coconut crabs hunt prey like this, it could have substantial ecological impacts. On these small islands, adult coconut crabs are by far the largest land animals. They may rule through an "island of fear" effect. Seabirds may avoid islands with lots of the crabs, to avoid getting themselves or their progeny eaten.

In line with this, Laidre found that if coconut crabs were living on an island, birds were less likely to, and vice versa.

"In areas where these guys are present and abundant, it would be a smart move, especially among ground-nesting birds, not to place eggs there," he says.

There may be a flip side. If an island has lots of birds, coconut crabs will find it hard to colonise, as they start off small and vulnerable. "If you have a bunch of birds there, it's going to be very hard to get bigger because they are going to eat you," says Laidre.

He now plans to set up remotely activated cameras with the aim of revealing what the crabs drag back to their burrows to eat and how often they hunt birds. ■



Slow but utterly deadly

Did star smash-up birth a huge neutron star?

WHEN two neutron stars smashed into each other in August, we weren't sure what was left over: a single colossal neutron star or a black hole?

Now Yun-Wei Yu at Central China Normal University and Zi-Gao Dai at Nanjing University in China have modelled this "kilonova" explosion, which lasts weeks or months. They think there is a neutron star at the

spot where the smash-up occurred.

There are three main theories for what could be left behind when two neutron stars collide: a black hole, a single neutron star that only lasts for a few milliseconds and then collapses into a black hole, or a stable neutron star that sticks around longer. If it is the latter, it is the biggest we have ever seen.

There may be clues in the kilonova. As the original neutron stars orbit each other in their death spiral, they can accelerate up to about a third of the speed of light, says Edo Berger at Harvard University. When they crash

and become one, the resulting object keeps that momentum. "If this neutron star exists, it's spinning extremely rapidly in the beginning, something like 1000 times per second, and pumping out all of this energy," Berger says. The energy pours into the ongoing kilonova, changing its light.

A hike in the kilonova's energy would also point to the collision

"If this neutron star exists, it's spinning 1000 times per second and pumping out energy"

leaving behind a neutron star, whereas a black hole is expected to cause a single gamma ray burst.

There does appear to be an extra burst of energy, which Yu and Dai say matches their model for a neutron star remnant (arxiv.org/abs/1711.01898). But Berger says that a burst of gamma radiation that came from the collision seems like a clue to a black hole.

This is the first time we have ever had any observations of a neutron star merger, so all the theories are still preliminary and many more will emerge in coming weeks, Berger says. Leah Crane ■



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AI spots malicious data leaks online

Timothy Revell

"I'VE spoken to people that have had websites set up in their name requesting child pornography, their bank accounts hacked and money stolen from their account, and their employer phoned and told they were alcoholics," says Amy Binns at the University of Central Lancashire.

These people were doxed – someone published their personal information against their will, in a way intended for dissemination and abuse, instigating a torrent of attacks from strangers. "It's incredibly scary and could result in losing your livelihood," says Binns.

Despite many individual cases catching the public eye, up until now there has been very little research examining the scale of the problem and who is involved.

A team from the University of Illinois at Chicago and New York University used an AI tool to gather 5500 dox files – documents full of private information intended for dissemination. These came from 2 million candidate files on pastebin, 4chan and 8chan, which are among the most popular file-sharing websites on which they

tend to be hosted. Most included home addresses, phone numbers, information about family members, and email addresses, along with usernames, passwords and credit card information.

Doxers justified themselves in the files by saying they perceived the victim to have done something bad either generally, or to the doxer. "These things range from 'you cheated on a video game', to 'I think you're in the KKK', or 'you're a child pornographer'," says Peter Snyder at the University of Illinois, who conducted the study.

One finding surprised the team: just 16 per cent of targets were women. However, the authors say it would be wrong to conclude that men are generally more likely to be doxed. Most of targets in the study were either hackers or gamers, both groups that tend to include more males.

This study wouldn't have caught some forms of doxing that primarily affect women. "Making a fraudulent Craigslist advert for sexual services and giving away a person's home address tends to affect women more," says Laura Thompson at City, University of London. These ads are often



Doxing is scary

placed by abusive ex-partners.

In the future, the team hopes the AI tool could be used by websites to spot dox files, and they are in talks with pastebin.com (which has unwittingly enabled many attacks). The website removes reported files, but by then it is often too late. Ideally, the company could use the tool to filter documents for human intervention – and then share the information with targeted people to warn them.

Recent changes to Facebook and Instagram's algorithms may have

helped cut down on this kind of abuse too. During the study, both sites changed their algorithms to show people more "positive" content. Abuse was not eradicated, but it would have been less likely to be seen, leading to fewer attacks on accounts held by the target. The changes seem to have reduced the number of doxed accounts going private. "This gives us some hope that focused efforts can help lessen the impact," says Snyder.

The study was presented at the Internet Measurement Conference in London earlier this month. ■

Gluten free? A sugar chain may be the real issue

GOOD news for gluten-intolerant fans of Eastern cuisine. Gluten might not be the bad guy after all, so people with non-coeliac gluten sensitivity should be able to eat soy sauce.

About 1 per cent of people have coeliac disease, an autoimmune disorder involving a bad reaction to gluten. But a further 12 per cent feel ill after eating foods like bread and pasta,

despite not having coeliac disorder.

In 2013, a study of non-coeliacs with gut issues found no difference in symptoms when these people ate identical meals that either lacked gluten, or were full of it. Jane Muir and Peter Gibson at Monash University in Australia wondered if fructans – sugar chains found in food including wheat, barley, rye and onions – might be the inciting factor instead.

They recruited 59 non-coeliac adults following gluten-free diets and got them to eat specific cereal bars for a week at a time. These bars all looked and tasted the same, but one type

contained gluten, another contained fructans, and the third had neither.

The fructan bar triggered 15 per cent more bloating and a 13 per cent increase in overall gastrointestinal symptoms than the control bar. But the gluten bar had no effect (*Gastroenterology*, doi.org/cf5s). This may explain why people with irritable bowels often improve on wheat-free diets but don't recover fully, says Muir.

"If fructans are to blame, it will open up a range of foods currently off-limits to gluten-free diets"

Evidence is growing that most people with irritable bowel syndrome (IBS) feel better when they cut out fructans and other hard-to-digest short sugar chains known as FODMAPs. These can lead to bloating.

If fructans are the real problem, it will open up a range of foods currently off-limits to gluten-free diets, says Katie Ellard, a gastroenterologist at Mater Hospital in Sydney, Australia. Soy sauce, for example, contains gluten but is low in fructans, while the fermentation process used to make sourdough bread strips away wheat's fructans. Alice Klein ■

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Personal Investing



Triton crashed into Neptune's moons

Leah Crane

IT CAME in like a wrecking ball. Neptune has one of the weirdest collections of moons in our solar system, and it's Triton's fault. The planet's largest moon probably smashed into the orderly moon system that was there before it arrived, knocking everything out of sync.

Planetary scientists have long suspected that Triton is an interloper from outside the Neptune system. Now they have calculated what the other moons may have looked like before the intrusion.

The other gas giants in our solar system – Jupiter, Saturn and Uranus – have fairly similar systems of moons. In these, the mass of the planet is about 10,000 times bigger than the total mass of the moons. For the most part, these planets have several small moons, all orbiting in the same direction as the planet spins.

But Neptune is different. It has several tiny moons either very close in or far away from the planet – most of which orbit in the direction of the planet's spin –

and one huge one, Triton, orbiting in the opposite direction.

Robin Canup at the Southwest Research Institute in Colorado and Raluca Rufu at the Weizmann Institute of Science in Israel used a series of computer simulations to figure out what the Neptune system was like before Triton barreled in. They found that it probably had a moon system similar in total mass to Uranus's. But that didn't last long.

"Triton crashed the party,"

says Canup. "It destroyed the well-behaved satellite system that was there before it."

To get from a serene Uranus-like system to what we see at Neptune today, three things have to be true: the early moons had to be small enough that they wouldn't destroy Triton as it crashed into them; they had to somehow slow Triton down so that it would be captured in the relatively close and circular orbit that it has now; and Neptune's outer moons had to remain intact.

"The question is, how do you capture Triton in an elongated orbit and then get it into this circular orbit? You have to dissipate some energy from it to slow it down," says Scott Sheppard

at the Carnegie Institution for Science in Washington DC.

Canup and Rufu found that Triton's gravity flung the smaller moons around. It also collided with some of them, slowing down and settling into its circular orbit. This process happened fast enough to stop Triton from hurtling through the outer areas of Neptune's system too many times, leaving the moons out there relatively unscathed (arxiv.org/abs/1711.01581).

"Now that we have some hold on what the original moons of Neptune were like, that can give us some clue as to what we should expect for extrasolar planets of that type," says Matija Cuk at the SETI Institute.

Unfortunately, it will be difficult to confirm the scenario that Canup and Rufu propose, even if we send a spacecraft to Triton to look. Triton is icy and seems to be geologically active, so ice is likely to have filled in any craters or scars from the moon's past misadventures, says Sheppard.

We have a better chance if we study what Triton is made from. "Triton is kind of a Frankenstein's monster moon," says Cuk. "Most of it is this original captured object, but if this research is correct then about 10 per cent of Triton comes from crashing into and absorbing these original moons." ■



WALTER MYERS/SCIENCE PHOTO LIBRARY

Forceful beginning

Charge your phone using indoor light

AMBIENT light may be all you need to charge your phone. Miniature solar panels created with an inkjet printer can harvest energy from artificial light and indirect sun.

Conventional solar panels typically use silicon to capture the sun's energy. But Sadok Ben Dkhil from Dracula Technologies and his team have developed a conductive plastic that can

utilise a wider range of wavelengths. "Our material can capture energy from indoor light, which isn't possible with silicon," says Ben Dkhil.

The lightweight panels include a photoactive layer sandwiched between two semiconductor sheets that help a conductive ink in the outer layer to extract the charge. A 5-centimetre-square panel can be created in about an hour using inkjet printing, which keeps the cost of producing the light-capturing panels low.

Ben Dkhil's solar cells can be tailored for a wide range of uses.

A panel could be integrated directly into a smartphone, for example, although it might be more effective to use a surface that is more regularly exposed to light. "You can imagine printing it on a T-shirt and using that to charge your phone," says Ben Dkhil.

Capturing energy from indoor light is a challenge since the intensity is much lower than sunlight. At the moment, Ben Dkhil's system can't

quite extract enough energy from indoor light to charge a phone in a reasonable time frame, but efforts have been improving at a steady pace. "In a few months' time, we should be able to charge a smartphone," he says.

In the meantime, Ben Dkhil and his colleagues plan to use their system to power sensors, such as those that monitor temperature and humidity in buildings, since these require only a small amount of energy. And they have created a parasol from their material that can be used to charge a phone outdoors. Sandrine Ceurstemont ■

"These miniature solar panels can capture a range of wavelengths to get energy from artificial light"



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A group of people, including scientists and photographers, are in a small white boat with a blue stripe. They are looking at a large whale that is partially submerged in the water. The boat has the name 'KUYIMA 9' written on its side. The background is a deep blue ocean.

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Prairie vole pairs split up if only one is a heavy drinker

HEAVY drinkers and abstainers don't make ideal couples. In humans, one partner drinking more than the other can be a recipe for a break-up. The same is true for prairie voles, one of the few mammals that form long-term monogamous pairs. This suggests the link between alcohol and break-ups may have a biological basis.

"There is an increase in divorce in couples in which there is discordant drinking," says Andrey Ryabinin at Oregon Health and Science University. No one knows why.

To find out, Ryabinin and Andre Walcott, also at OHSU, studied prairie voles. "They maintain the same pair bond

for their entire lives," says Ryabinin. They also willingly drink alcohol, unlike most rodents.

The two researchers gave pair-bonded voles either water, or alcohol and water. Later, the voles were offered a choice between their partner and a new mate. Males tended to stick by their partner if both had drunk similar amounts of alcohol. But if only the male had been drinking, he was more likely to mate with a stranger. Ryabinin presented the results last week at the Society for Neuroscience meeting in Washington DC.

The study is fascinating, says Zoe Donaldson at the University of Colorado, Boulder. But she says it doesn't necessarily show that discordant drinking leads to broken relationships. It could be that some voles had weaker bonds and that influenced how much alcohol they drank.

Tracing an interstellar comet's home

AN APPARENT interstellar asteroid is flying out of our solar system after first being sighted in October. Astronomers are trying to trace where it came from, and what this visitor might tell us about how planets form.

The asteroid – named 1I/'Oumuamua, which means "to reach out from afar" in Hawaiian – sped through our solar system, steeply entering from above the

plane on which the planets orbit the sun. The gravitational pull of our sun flung it back out of our solar system at a new angle, never to return again.

Eric Gaidos at the University of Hawaii at Manoa and his team have now calculated that it might have formed in loose star clusters in the constellations Carina or Columba (arxiv.org/1711.01300). They theorise that 1I/'Oumuamua

formed close enough to its star to be made mostly from rock rather than volatile ices. It could have been ejected by a collision during planet formation, and sent hurtling free of the star's gravitational grasp about 40 million years ago.

If Gaidos and his team are right, further collisions could have knocked free other objects towards our solar system, which means we may see some of this asteroid's cousins.

Daytime wounds heal twice as fast

IF YOU'RE going to get injured, try to do it during the day. Wounds seem to heal in half the time if sustained during daytime hours rather than at night.

Nathaniel Hoyle of the MRC Laboratory of Molecular Biology in Cambridge, UK, and his colleagues have discovered that genes in a type of skin cell switch on and off during day-night cycles. These cells, called fibroblasts, help close wounds after skin has been cut.

The team then analysed data from a burn injuries unit at the University of Manchester, UK, finding that, on average, daytime wounds healed in 17 days, while similar burns sustained at night took 28 days (*Science Translational Medicine*, doi.org/cf45).

"We found that how well you heal depends on what time of the day you're injured," says Hoyle. "Healing in the day can occur 60 per cent faster."

Grow your own sea urchin and foie gras

THE Shojinmeat Project in Japan is teaching people how to make lab-grown meat themselves at home.

Culturing meat at home can be more environmentally friendly and no animals are killed.

Many people are having a go – from a woman who works at a fish market by day and cultures sea urchin meat by night, to high-school students culturing shellfish in their refrigerators. Another group recently grew a small piece of foie gras that they split six ways. "The problem was that none of us were rich enough to know the taste of the real thing," says Shojinmeat founder Yuki Hanyu.

Shojinmeat has now released instructions online on how to build a bioreactor for culturing meat at home, along with a recipe.

Facebook's Harry Potter profile pics

IN THE wizarding world of Harry Potter, people in portraits and pictures don't just sit there. They smile, gasp, wink or get up to mischief. Now Facebook has been hard at work making this a reality for your profile pic as well.

The new tool, developed with Tel Aviv University, Israel, can animate your picture to flash a happy, sad or angry expression. To create these "reactive profile pictures", the tool uses a "base" video of another, completely different person, and maps their changing expression onto the original still image.

In a study, half the people who saw the animations were fooled into thinking that they were real videos.

The team foresees that this might be used, for example, when someone clicks "like" on a post, with the recipient's profile picture responding with a smile or wink.

In the future, the tool could be combined with natural language processing so that when you are messaging with someone, you see an animated version of the person reacting to what is being said, rather than a static image.

The project will be presented at the Conference on Computer Graphics and Interactive Techniques in Bangkok, Thailand, later this month.



2010 UNIVERSAL ORLANDO RESORT/GETTY

Humans blamed for Caribbean ground sloth extinction

WHAT killed giant ground sloths? Was it humans or a natural event, like the end of the last ice age? The question is endlessly debated. But the answer, in the Caribbean at least, now seems clear: it was us.

Humans got to North America around the end of the last ice age, when many large mammals like dire wolves and ground sloths vanished. Attributing blame here is near-impossible.

But the Caribbean islands are different, say Siobhán Cooke at Johns Hopkins University in Baltimore, Maryland. The ice age

ended 12,000 years ago, but we only made it to most of the islands 5000 years ago.

Cooke and her colleagues built a timeline of extinction and human occupation. This shows it was the arrival of humans that saw off the Caribbean's giant ground sloths, plus its enigmatic monkeys, giant rodents and much else (*Annual Review of Ecology, Evolution and Systematics*, doi.org/cf47).

There was a second extinction 500 years ago when Europeans showed up. Small mammals succumbed. The endemic rodents,

shrew-like insectivores and many bats didn't stand a chance, says Cooke. The newcomers let loose cargoes of rapacious Old World mammals like cats, rats, dogs, cows and mongooses. Of 130 Caribbean mammals found in the fossil record, only 73 survive today.

"There is rarely a smoking gun where prehistoric extinctions are concerned, but the authors show that most West Indian losses can be correlated with the arrival of people," says Ross MacPhee of the American Museum of Natural History in New York.

Coffee linked to heart health

TIME for another cup? An analysis of more than 17,000 adults has found that coffee drinkers have a 7 per cent lower risk of developing heart failure for every cup of coffee they consume per week.

Heart failure is a progressive condition in which the heart cannot pump all the blood the body needs. This results in insufficient oxygen and nutrients being delivered to the rest of the body, and can lead to death.

The finding, from Laura Stevens at the University of Colorado and her team, was presented at a meeting of the American Heart Association in Anaheim, California, this week.

It is unclear why coffee would cut the risk of heart failure, says Stevens. "We don't yet know if it is the coffee intake itself or another behaviour that might go along with it," she says. For example, coffee drinkers may simply have healthier lifestyles.

Two other studies published earlier this year also found that coffee drinking seems to significantly reduce the chance of dying from heart disease.

Stevens plans to study the compounds in coffee to find the reason for any protective effect.



PIRTRAVEL/ALAMY STOCK PHOTO

Crowd size is key to wobbling bridges

A BRIDGE will sway if a "magic number" of pedestrians cross at once.

This happened when London's Millennium Bridge first opened. Igor Belykh at Georgia State University in Atlanta says that was due to people's footfalls matching the bridge's natural frequency, the rate at which it must be subjected to force to start moving. Every bridge has a natural frequency based on its length, width and other aspects of its design.

Imagine you are trying to get a swing to rise. If you rock too quickly or too slowly nothing happens. But moving your legs at the right

interval gets you swinging. Similarly, if the timing of footfalls on a bridge match its frequency, it will sway, too.

It used to be believed that the bigger the crowd, the bigger the wobble. But Belykh's model shows that it isn't just synchronised steps that start the swaying. Instead, it is a numbers game. Once the crowd reaches a critical size, there is a noticeable jump in swaying.

Once this jump happens, the fact that we all move similarly to counteract the motion can make a bridge sway even more (*Science Advances*, doi.org/cf7f).

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My body, my genes

Biohackers want to alter their own DNA with the gene-editing technique CRISPR. Should we stop them, asks **Alex Pearlman**

GENE editing is entering the mainstream. CRISPR, a cheap and easy technique for making precise changes to DNA, has got researchers around the world racing to trial its use in treating a host of human diseases.

But this race is not confined to the lab. Last month, Josiah Zayner, a biochemist who once worked for NASA, became the first person known to have edited his own genes with CRISPR.

During a lecture about human genetic engineering that was streamed live on Facebook, Zayner whipped out a vial of edited DNA and a syringe, then injected himself. Now, following in his footsteps, other biohackers are getting ready to take the plunge and tinker with their own genes.

Away from the strict controls of formal science, this self-experimentation might seem dangerously reckless. But if people are allowed to modify their own body through cosmetic surgery, tattoos and other augmentations, should a person's own genome really be off limits?

Zayner's experiment was intended to boost his strength by removing the gene for myostatin,

which regulates muscle growth. A similar experiment in 2015 showed that this works in beagles whose genomes were edited at the embryo stage. He injected himself with a copy of his own DNA that had been edited using CRISPR to remove the gene.

Robin Lovell-Badge, a leading CRISPR researcher at the Francis Crick Institute in London, says Zayner's experiment was "foolish" and could have unintended consequences, including tissue damage, cell death, or an immune response that attacks his own muscles.

"Will allowing broad access to CRISPR risk creating a group of 'superhumans' with enhanced abilities?"

"He's got a very large ego and he wants to make his muscles the same size as his ego, maybe," says Lovell-Badge.

A single injection is unlikely to cause a lasting change, but Zayner's stunt shows that it is possible for individuals to use the gene-editing technology. The general consensus is that a course of two or three injections per week

for a few months is required to see a permanent alteration.

That may happen soon. Zayner has created a kit that is for sale through his company, The Odin, in Oakland, California, which will allow others to replicate his work.

Rich Lee, a biohacker in Utah who is colour-blind, says he wants to use Zayner's kit to not only cure his colour blindness, but take his eyesight to the next level. He wants to see into the ultraviolet spectrum, a rare genetic mutation called tetrachromacy that is sometimes found in women.

Another biohacker, David Ishee from Mississippi, whose previous attempts to use CRISPR in dogs were shut down by the US Food and Drug Administration (FDA), also intends to boost his muscle mass. He won't be using CRISPR, but will inject an extra copy of the gene for follistatin into his cells. Where myostatin inhibits muscle growth, follistatin increases muscle mass and has been linked with accelerating metabolism.

These biohackers believe it is a basic human right to access and edit one's own genome. "I am of the opinion that your genome is your own," says Ishee. "I think that it is important that people have the ability to choose what kind of gene expression they want for themselves."

This ethos of "my body, my choice" is used to underpin arguments for health, reproductive and disability rights, but should it extend to the right to edit our own genes? What about the potential unintended effects of using untested technology? And will allowing broad access to CRISPR risk creating a group of "superhumans" with enhanced senses and abilities?



THE ODIN INC



Just supply your own cells

These are some of the many issues that have plagued scientists and ethicists for years. Recent papers from the US National Academies and the Nuffield Council on Bioethics in the UK have attempted to grapple with these questions, including whether there is a moral difference between gene editing for medical therapy versus enhancing ordinary abilities.

John Harris, a bioethicist at the University of Manchester, UK, who has written about human enhancement since the 1980s, does not believe there is a significant difference. He thinks the biohackers could help move the arguments along and hasten the safe use of CRISPR in humans.



Josiah Zayner has edited his DNA

“There is a long and noble history of both doctors and scientists experimenting on themselves,” says Harris. “It has proven tremendously valuable in the public interest.”

And as there is nothing to stop people from modifying themselves in other, more socially acceptable ways, can biohackers be stopped on ethical grounds?

“Can it be wrong to do this to see if these therapies work successfully when compared to all the other things that people are allowed to do to themselves?” says Harris. “People pierce themselves, people tattoo themselves, and even cut off their own limbs.”

Still, he stresses that success in at-home experiments doesn’t

mean genome editing is ready to be offered for sale to the general public.

Hard questions

The biohackers disagree. Zayner says he has covered his bases, in case of any legal trouble. His site says the samples he is selling are not meant for human use. But that won’t stop anyone from following the instructions he has laid out for how to edit the adult human genome. With The Odin processing thousands of orders, it would be ridiculous to suggest that some of those orders aren’t being used for human experimentation.

Bizarrely, because The Odin’s kits are not technically drugs, and Zayner is not attempting to actually practice medicine on anyone or market a medical device, the FDA will not yet regulate at-home genome editing. At the moment, self-experimentation is not illegal and so DIY CRISPR resides in a legal grey area in the US and UK.

That isn’t true everywhere. In Germany, which clamps down on anything that carries even the slightest whiff of eugenics, the kits set off alarm bells with officials in Bavaria earlier this year and were banned from use in homes and schools.

Within the regulatory debate, it is also important to note that most biohackers aren’t intending to hack anyone other than themselves – but they are keen to help others do it at home, and sharing information transparently is tantamount. It is their version of peer-review, mostly conducted on forums and social media.

“I’m definitely going to be collecting a lot of data and sharing it,” says Ishee. “My goal is to put everything out there. There is some probability that it won’t work, right? But maybe the next guy gets it right.”

And what if “the next guy” is a future Olympic medalist? The World Anti-Doping Agency (WADA) announced last month that it would ban all forms of gene therapy or gene doping from international competitive sports from 2018. However, it’s unlikely that international testers will be able to detect most forms of gene editing, and with all the free-flowing information about various experimental enhancements, it seems even less likely that WADA will be able to enforce this ban. “WADA is a joke,” says Ishee.

Günes Taylor, who also works with CRISPR at the Francis Crick Institute in London, says she is conflicted by these home-brew experiments.

“Part of me is, like, ‘that is so awesome’... but it won’t work,”

she says, insisting it will be more difficult than the biohackers think. “CRISPR has been sold as a cure-all... but actually getting it to do the thing that you want it to do successfully is more complicated.”

Taylor thinks there could be scientific benefits to monitoring how biohackers modify their bodies, giving us more information about how CRISPR works in humans, but the potential for harm means this

“Self-experimentation is not illegal and so DIY CRISPR resides in a legal grey area in the US and UK”

would be unethical, and DIY experiments should be more heavily regulated.

But biohackers think the trouble is worth the risk, and there is no ethical reason they shouldn’t be allowed to use their own bodies to try to push science forward.

Perhaps instead of trying to take experiments away from the DIY community, we need to accept that we stand on the cusp of significant changes to the human genome – because they are going to do it anyway.

“We have this knee-jerk reaction that your genetics should always be up to chance, that there shouldn’t be a choice,” Ishee says. “But I don’t think that’s true or right. If the technology exists to give you the choice, you may as well make it.”

The question now is how to make sure genome editing is safe and accessible to use for the wider public, who may not fully understand the risks of self-experimentation. Lovell-Badge says he supports the biohacker community, and has attended their meet-ups, but they must be responsible and acknowledge possible consequences of spreading CRISPR widely, or face a crackdown. “It’s very hard to write regulations which allow people to play around with science in their garage,” he says. ■

Under the spotlight

Power really does corrupt, which means we need even greater scrutiny of those at the top, says **James Bloodworth**

IN RECENT weeks, the UK parliament has been beset by accusations about powerful men sexually harassing female MPs, journalists and party activists.

Those revelations followed similar claims levelled against big names in Hollywood. Most recently, the leak of financial documents known as the “Paradise Papers” exposed a network of tax-avoidance schemes used by the world’s super-rich and famous.

A cascade of revelations about those in positions of authority, and high-level instances of sleaze, avariciousness and dishonesty is hardly new of course; in 1887, the historian Lord Acton famously wrote: “Power tends to corrupt...”

This latest clutch of scandals seems another depressing example of the apparent connection between unethical behaviour and the holding of



power. What is the truth about that relationship?

Studies suggest that when people obtain the whip-hand over others, it can unleash an unsavoury side of their personality. The most famous example is the 1971 Stanford prison experiment, in which one group of students was assigned to serve as prison guards over another group. The experiment was halted after “guards” began to abuse those in their charge.

Swiss research in 2014, in which participants were asked to play a “dictator game”, found that even those who started with good intentions weren’t immune to power’s corrupting influence.

Does this absolve the powerful in some way? No. There is also evidence to suggest that, rather than corrupting all it touches, power amplifies traits that were there to begin with.

Odd one out

When it comes to climate, Donald Trump’s US is now in a club by itself, says **Owen Gaffney**

WITH Syria’s decision to join the Paris Agreement on climate change, the US now stands alone.

The war-torn state had been one of only two nations rejecting or refusing to sign the accord after a third holdout – Nicaragua – announced in September it was in.

Syria is a dysfunctional basket-case of a failed state. Its economy

is broken and its emissions small. Yet its intention to join the Paris deal, announced last week at the annual UN climate talks in Bonn, Germany, is symbolic, but not for obvious reasons.

Three decades of data show that nearly a quarter of conflicts in countries with existing ethnic tensions, like Syria, coincide with

climate shifts such as heatwaves and droughts. So climate change can significantly reduce resilience in politically fragile societies, even if the direct link with conflict is complex and ambiguous.

What of the US? Its intention to leave the Paris Agreement is far from symbolic. The world’s largest economy and second largest emitter of greenhouse gases is aggressively rolling back policies aimed at reining in emissions, even as its scientists produce the

strongest case yet for immediate and large-scale action, and clean energy becomes competitive.

Earth is on a knife edge. The US Global Change Research Program’s recent 447-page report has an ominous final chapter “Potential Surprises: Compound Extremes and Tipping Elements”.

The authors say that human activity has “significant potential” to result in unanticipated climate shocks and there is a “broad consensus that the further and faster the Earth system is pushed... the greater the risk”.

The very last paragraph of the report states: “climate models... are more likely to underestimate

“There is simply no room for complacency. We are sailing scarily close to Earth’s tipping points”

A 2012 study found that power simply exacerbated pre-existing ethical tendencies. When a participant thought of themselves as compassionate, generous and fair, granting them perceived power led them to make more community-centred choices.

"Power isn't corrupting; it's freeing," Joe Magee, a researcher and professor of management at New York University, recently told *The Atlantic*. "What power does is that it liberates the true self to emerge," he added. In other words, power removes the social filter through which we tend to moderate our behaviour. A person who uses power for corrupt ends was probably corrupt all along.

Part of the problem may be that the less altruistic are perhaps more single-minded in pursuit of power than prosocial people.

Power can corrupt, yet there is nothing inevitable about the process. Those dragged over the coals for wrongdoing are being brought low by their own choices.

Power didn't make them do it, but it may have led them to believe they could get away with it. The answer is to do much more to ensure those at the top have no hiding place. ■

James Bloodworth is a writer based in London

than to overestimate the amount of long-term future change".

There is simply no room for complacency. As things stand, we risk hitting 2°C of warming above pre-industrial temperatures in about two decades. We are sailing scarily close to Earth's tipping points.

As the storm clouds continue to gather, if there is a silver lining to Donald Trump's actions, it is that he seems to be strengthening resolve in the rest of the world rather than weakening it. ■

Owen Gaffney is an Anthropocene analyst at the Stockholm Resilience Centre at Stockholm University, Sweden

INSIGHT Medical marijuana



Pots of pot

Time for cannabis vendors to grow up

Clare Wilson

CANNABIS can make scars disappear, reverse Alzheimer's disease and even cure cancer – that is, if you believe some of the wilder health claims made by US firms in states where medical marijuana has been legalised.

Unfortunately, such assertions aren't based on a shred of good evidence. Not only are consumers being ripped off, but their health can also be endangered. Little wonder that the US cannabis industry is sometimes dubbed a Wild West operation.

Marijuana has a long history of therapeutic use. Modern researchers have found some supporting evidence for a range of benefits that include relieving pain, muscle spasms, nausea, suppressing epilepsy and aiding sleep.

It is hard to know the exact nature and scale of the effects because there are few large-scale, good-quality trials. This is partly because research has long been stymied by the plant's classification as an illegal drug. It can take researchers years to get past the red tape and official disapproval.

In the meantime, thanks to changing public attitudes, there has

been a spreading decriminalisation of cannabis in various forms, including in Spain, Portugal, Uruguay and Canada. More significantly, 29 US states and Washington DC now allow medical use.

Some see this shift as a humane and progressive step, but in the more market-led US, it has also caused an explosion of firms marketing cannabis products on the basis of health claims unsupported by evidence. One of the most egregious is that it can cure cancer. Earlier this month, the US Food and Drug Administration (FDA) had to

"Of all the things that are called a medicine, no drug is less regulated than marijuana"

send warning letters to several firms guilty of misleading people in this way.

Cannabis has sometimes been given to cancer patients because its anti-nausea effect can be helpful after chemotherapy, and it can boost appetite – which probably explains why pot smokers are prone to the munchies. But there is no good evidence it shrinks tumours. Alarming, some cancer patients

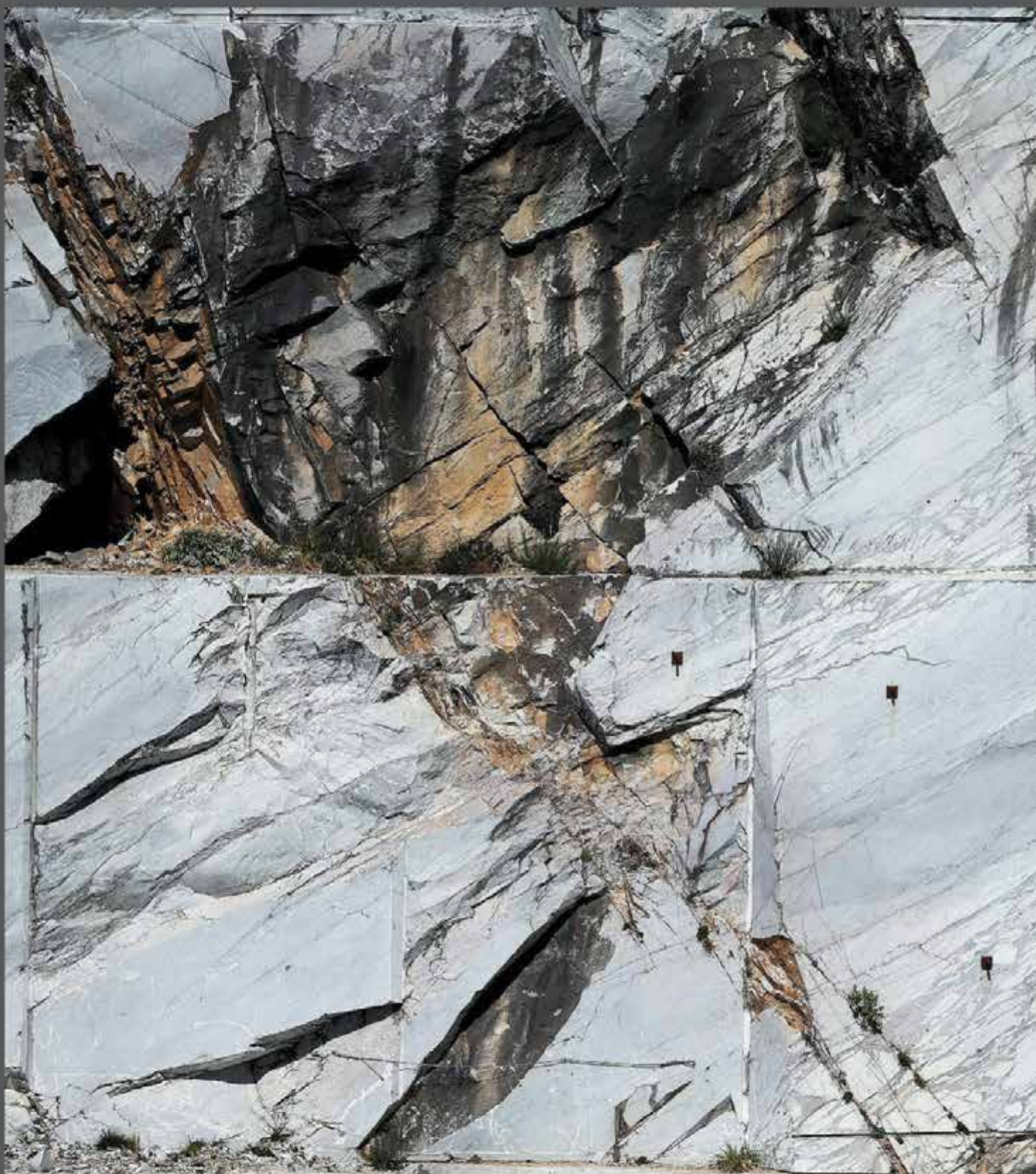
are even rejecting chemotherapy in favour of cannabis products.

As well as false advertising, the market also suffers from lack of quality control. Over two-thirds of US medical cannabis products sold online have either a higher or lower amount than stated of the therapeutic component, cannabidiol, it was revealed last week.

"Some had almost nothing in there," says Marcel Bonn-Miller at the University of Pennsylvania in Philadelphia, who did the investigation. The consequences of such bogus remedies could range from inconvenient to dangerous. For instance, someone trying to suppress their epilepsy could have a seizure.

Part of the problem is that in the US, medical cannabis is in a legal limbo. Although it is approved at state level, it is banned under federal law, and so the FDA cannot regulate cannabis-based products as it does pharmaceuticals and other remedies. The recent warning letters are welcome, but the agency cannot inspect manufacturing facilities or check cannabidiol levels.

"Of all the things that are called a medicine, no drug is less regulated than marijuana," says Keith Humphreys of Stanford University, California. "We have given it all the privileges of being called a medicine with none of the responsibilities." As cannabis becomes increasingly legalised, vendors must stop acting like street-corner dope dealers, and grow up. ■





Marble muse

DON'T look down. This is the Cervairole marble quarry on Mount Altissimo, high in Italy's Apuan Alps. Safely roped in, these workers are removing loose rocks that might fall when marble blocks weighing nearly 10,000 kilograms are removed.

Despite being more than a kilometre above sea level, the marble here was discovered by the Renaissance sculptor Michelangelo, who trekked up Altissimo's slopes 500 years ago. He believed that the marble he found there - "crystalline, reminiscent of sugar" - may have been better than the Carrara marble he had used to carve his statue *David*.

Michelangelo planned to use Cervairole marble in designs for the San Lorenzo cathedral in Florence, so he set out trying to transport it down the mountain. But after three years of difficulty trying to establish a quarry and a connecting road, Pope Leo X cancelled the plans.

Three centuries later, the Henraux company established the Altissimo quarries that are still active today. Auguste Rodin, Henry Moore and Joan Miró have all sculpted Altissimo marble, and the rock has been used to furnish St Peter's Basilica in the Vatican and the Sheikh Zayed Grand Mosque in Abu Dhabi. Aylin Woodward

Photographer

Alessandro Bianchi

Reuters



Inconceivable truth

We are heading for a male fertility crisis, finds **Moya Sarnier**.
It's time to face the issues

MY FATHER was 50 when I was conceived. My mother, at 39, was called an elderly primigravida, a term used to describe a woman who becomes pregnant for the first time at 35 or older. There is no name for the male equivalent, though my father was delighted to call himself an “elderly primigravidad”.

Jokes aside, we are used to thinking of fertility and healthy pregnancy as predominantly the domain of women, who are warned all too frequently of the dangers of leaving it too late to start a family. This hasn't been the case for men.

But it might be time for a reality check. In recent months, a number of studies have been building a picture of a looming male fertility crisis. Sperm counts are dropping, and it turns out that for men – far from having all the time in the world to become dads – the clock is ticking too.

In a society where couples are choosing to conceive later in life, we are heading towards a perfect storm. “If the decline in sperm counts is real, then the combination of this and our general desire to have our children later in life is a total disaster,” says Allan Pacey at the University of Sheffield, UK.

The fact that women, but not men, are so regularly harangued about their fertility perhaps isn't surprising when you consider that women are born with all the eggs they will ever have, which dwindle and age with time, while men produce sperm throughout adulthood (see “It takes two”, overleaf).

You might assume men have little to worry

about. But if the latest headlines are to be believed, something is amiss. Perhaps the most striking news came in July, with the discovery that sperm counts have decreased by almost 60 per cent in richer countries in the past 40 years, and are continuing to fall by 1.6 per cent every year (no such decline was seen in poorer countries, although there are fewer studies to go on). The finding came from a review of more than 185 different studies of sperm concentration and total sperm count in men between 1973 and 2011. “The results were truly shocking,” says Hagai Levine at the

“A substantial proportion of young men have a sperm count that impairs fertility”

Hebrew University of Jerusalem, Israel, who led the analysis. “I thought: I know something that the world needs to know. This is a clear and present danger that we are already facing.”

This isn't the first study to find that sperm counts are dropping, but previous efforts were considered controversial. This one is much larger, and addresses problems with the previous work – for instance making sure all the papers included in the review used the same techniques and, crucially, that they didn't include men with known fertility problems.

Even Pacey, a self-confessed “grumpy sceptic” about declining sperm, says that this research made him take notice. “I have to

admit that I thought, ‘Oh, there might be something in this now,’” he says. “I'm a reluctant convert, in some ways.” Even so, he argues that the only way to prove conclusively that sperm counts are dropping would be to recruit large numbers of 18-year-old men each year for 10 years and count their sperm, thus building a picture of how it changes over time. He and others have proposed this kind of study, but not received funding.

In the meantime, the most crucial thing is the current sperm count levels, says Richard Sharpe, who studies male reproductive disorders at the University of Edinburgh in the UK. “A substantial proportion of young men have a sperm count that will impair their fertility – and that is the most important factor in all this,” he says.

That's backed up by studies in European countries such as Denmark, Finland, Estonia, Latvia, Lithuania and Germany over the past 15 years. “In all countries large proportions of men have a semen quality that may negatively affect their fertility,” says andrologist Niels Jørgensen at Rigshospitalet in Copenhagen. “For some 10 to 15 per cent, it may be so low that they need fertility treatment to become fathers; another 20 to 25 per cent could expect to experience a prolonged waiting time to pregnancy, compared to men with optimal semen quality.”

What causes this, however, remains murky. “The truth is that we don't have a good answer,” says Sharpe. The fact that sperm counts have dropped so fast over such short time scales suggests the causes are lifestyle ➤



SASHA GULIS/IMAGE SOURCE/PLAINPICTURE

Men have a ticking clock too - but whatever age you have kids, getting poked in the eye still hurts
Below: a deformed sperm cell

and environmental, as genetic changes would take longer to be seen in the population.

One possible explanation lies in the fact that, even though men produce sperm throughout adulthood, their ability to do so is largely preprogrammed in the womb. The idea is that things like low sperm count can originate at this time, probably because of impaired production of male sex hormones by the testes, known as testicular dysgenesis syndrome (TDS), or a reduced number of sperm-supporting cells (see “Sperm”, right).

But we don’t know why some fetuses develop TDS while others don’t. This is particularly difficult to research as there is a period of 20 or more years between its causes in the womb and when we see low sperm counts in adults. Studies that investigate these causes and follow up later in life are impossible to get funded, and retrospective studies are impossible to carry out, as women don’t record or later remember all aspects of their lifestyle and diet during pregnancy.

The exception to this is smoking, which women do remember. In the UK, for instance, 10.6 per cent of pregnant women were smokers at the time of their delivery between 2015 and 2016, rising to 25 per cent in some areas. Four studies show that sons born to women who reported smoking heavily while pregnant have a sperm count as much as 40 per cent lower than normal levels as adults. “This is one of the best pieces of epidemiological evidence showing how fetal events might affect sperm count in adulthood,” says Sharpe.

For other prospective environmental culprits, such as plastics, painkillers and potentially hazardous chemicals,

researchers grow human testes cells in animal models. While exposure to plastics didn’t seem to have an effect, painkillers did – a finding Sharpe says must be investigated, since the majority of women use painkillers in pregnancy.

Hard to conceive

But Jørgensen says that only looking at causes one at a time is problematic because this doesn’t give us the whole picture. “The reality is that humans are surrounded by thousands of chemicals that don’t seem to pose any threat – but in combination, they do,” he says.

Whatever the causes of TDS, its effects are lifelong: a man’s sperm production is capped at the limit preprogrammed in the womb. But it can go down. And one of the factors affecting this is age. The crucial difference with women’s biological clocks, however, is

that these stop ticking with the menopause, whereas men’s clocks continue to tick until death, just a bit slower.

It’s hard to test the effects of this “in the wild” but a recent study of 19,000 IVF cycles showed just how much of an impact a man’s age can have on a couple’s chances of conception. “Regardless of a woman’s age, if her partner was older, we often saw a decline,”

“Regardless of a woman’s age, if her partner is older conception rates drop”

says Laura Dodge at Beth Israel Deaconess Medical Center, who led the study (see diagram, right).

Her study didn’t find any clear age when that decline hits, but others have. When Bronte Stone and colleagues at Reproductive Technology Laboratories in Los Angeles looked at sperm samples from 5081 men aged between 16 and 72, they found that sperm quality and quantity deteriorated after the age of 35. Others suggest this decline begins at 40 – the cut-off age for sperm donation.

A man’s age doesn’t just affect conception rates, it also has a bearing on the health of the offspring. Studies have found that those born to fathers aged 45 and over are at an increased risk of psychiatric disorders including psychosis. And research looking at everyone born in Sweden between 1973 and 2001 found that when compared with a child born to a 24-year-old father, one born to a 45 year old is 3.5 times more likely to have autism, 25 times more likely to have bipolar disorder and 2.5 times more likely to attempt suicide or have a substance abuse problem.

The issues arise because sperm comes from the same population of stem cells in the testes for a man’s entire life. These have to replicate over and over, and with every cell division there is a chance of mutation. “They’ve probably divided about 800 times by the time a man is 40, and a consequence of all that cell division is that errors start to creep into the process,” says Pacey. This affects the genetic quality inside the sperm head, so that when a sperm meets an egg, it is less able to fertilise it. “And if it does the job, you’re more likely to have a child with a problem. It is a very, very small increased risk, but when you look at big population studies, you see it,” says Pacey.

Should this change the way we think about fertility? In reality, the woman’s age has by ➤



STEVE GOSCHWESSNER/SPL



It takes two

Fertility problems aren't just a woman's issue

Eggs

Women are born with all the eggs they will ever have – around a million. This dwindles to around 300,000 by the time they reach puberty.

By age 30, most women will have about 35,000 eggs left, and the rate of decline increases around the age of 32.

As well as quantity, age also

affects egg quality. It's not entirely clear why, but one reason is that older eggs encounter more problems during cell division. They are also less likely to be fertilised, and if they are, their chances of implanting in the uterus lining or developing normally are lower. According to the American Society for

Reproductive Medicine, women's best reproductive years are the 20s. But in the developed world the average age for women having their first child is pushing towards 30 – or higher in some countries. A 30 year old woman has a 1 in 5 chance of getting pregnant each month she tries.

Sperm

Sperm are produced continually after puberty and a whopping 1000 come off the production line every second – each having taken around 10 weeks to develop.

For a couple wishing to conceive, the sperm count matters – to a point. For sperm counts of 40 million sperm per millilitre of ejaculate and above, the chances of conception are roughly the same (see graph, right). Anything below this, however, is considered subfertile.

One crucial factor that determines a man's ability to produce sperm is the number of Sertoli cells in the testes. These help sperm to develop, but each can only support a certain number of sperm at one time.

The number of Sertoli cells is mostly set during the six months either side of the time that the man was born. As a result, there is evidence to suggest that a woman's lifestyle while pregnant – for instance if she smoked – can

have an effect on her son's sperm count later on (see main story). The effect of other chemicals and pollutants is harder to study.

Men who have a low sperm count are also more likely to have lower sperm quality – including reduced motility and abnormal shape. What's more, a man's age affects sperm quality as all sperm are derived from the same set of cells in the testes, and the more often they divide, the more likely it is that errors will occur.

What are the chances?



1 in 7 couples in the US have fertility problems

1/3

problem is with the man

1/3

problem is with the woman

1/3

can't be identified, or the problem is with both partners

SOURCE: CDC

No matter the age of his partner, a man's age can affect the chances of conception

WOMEN	MEN	BIRTH RATE*
< 30	30-35	73%
< 30	40-42	46%

SOURCE: DODGE/ESHRE

THIS STUDY LOOKED AT TOTAL BIRTH RATE FOR UP TO 6 IVF CYCLES PER COUPLE

One half of a whole

Sperm counts are in decline

1.6%

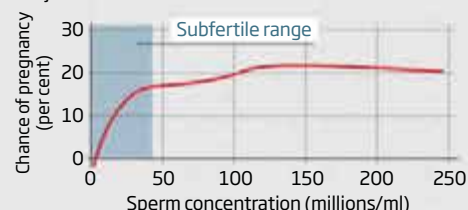


Yearly decline in men's sperm count in the West

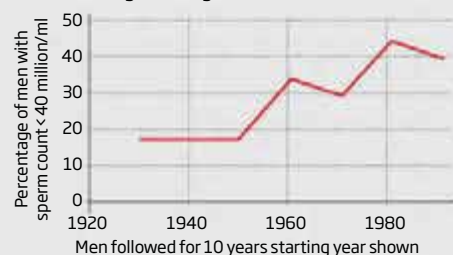
SOURCE: HUMAN REPRODUCTION UPDATE

Men's fertility

Sperm counts below 40 million per millilitre of ejaculate are considered subfertile



There is a trend showing the number of men in the subfertile range is rising



SOURCE: DOI 10.1038/embor.2012.50

Some lifestyle factors are thought to lower sperm count

(see overleaf for more details)

MYTH:

Cycling



LIMITED EVIDENCE:

Laptops and cellphones



MOST EVIDENCE:

Tight pants, saunas and hot tubs



SPERM-BOOSTING LIFESTYLE?

Jacuzzis, cycling, cellphones, drugs, laptops, tight pants, fatty foods... The headlines are full of habits that we are told can dent a man's fertility. But what's the truth?

In reality, "there isn't a definitive list" as the data is often contradictory, says Allan Pacey, who studies male fertility at the University of Sheffield, UK. "The biggest risk we found was wearing tight underwear."

This is thought to be related to the testicles being too warm, although we aren't sure of the exact mechanism. Other studies have suggested hot baths can have the same effect, and the US Centers for Disease Control lists frequent sauna and hot tub use as a potential risk factor. Pacey's research also suggests that smoking cannabis can temporarily affect the size and shape of sperm.

Men are often advised to eat a Mediterranean diet, and there are hints this could help boost sperm count and quality. This may have to do with the sperm's outer membrane, which plays an important role in recognising the egg, binding to it and burrowing into it. "Saturated fats, very prevalent in the Western diet and not so prevalent in the Mediterranean diet, may mean that you could end up with an altered fatty acid composition in your sperm membrane," says Richard Sharpe at the University of Edinburgh, UK, which could affect sperm function. However, research is mainly in animals - evidence for humans is still inconclusive.

Cycling has previously been linked to sperm damage, but a recent study of 5000 cyclists found no association between cycling time and infertility. And using cellphones or laptops connected to wireless internet on the lap could both affect fertility, but the findings are far from conclusive. As Pacey puts it: "These studies are difficult to do and no one will fund them."



Back on your bike. A study of 5000 cyclists found no effect of cycling time on infertility

far the most influence over the chances of a healthy pregnancy, but the father's age matters more than we think. "From my experience, it seems people are still focused almost exclusively on the woman's age," says Dodge. "If a couple is considering the woman's age in terms of when to have kids, they should probably worry about his to some degree as well."

"This underlies the fact that we understand very little about male fertility"

But for couples experiencing fertility problems, there is little to be done if the cause of the issue lies with the man. "We have no effective therapies to improve male fertility," says Pacey. "If we did, that would be a game changer." Treatments for women include IVF, a range of hormone treatments to boost ovulation as well as surgical procedures; for men, there are few effective options.

This underlies a striking fact - that we understand surprisingly little about male fertility. Earlier this year, the World Health Organization described current knowledge of male infertility as "very low". The UK Medical Research Council has since issued a call for projects in need of funding.

"The major questions that we were asking 30 years ago about how male reproduction works we still don't have any answers to," says Sharpe. "It is a fundamental ignorance, and it hampers our ability to interpret data, and to manage an infertile male, because we have very, very little that we can offer." Doctors recommend that men make general healthy lifestyle changes, but little of this advice is

evidence-based (see "Sperm-boosting lifestyle?", left).

And until men discover they have a fertility issue, they don't want to consider it, says Pacey. "I think men are mostly oblivious to their fertility and to the risks to their fertility." The evidence backs this up. Last year, the first large-scale survey that focuses solely on men's knowledge of male fertility took place in Canada and found that men were only able to identify around half of the risk factors and health issues associated with male infertility.

Reframing the conversation about fertility to include men should help address this. It could also offer relief to those men who also feel a social pressure to have children by a certain age. This "social clock" is rarely talked about among men, which can be very hard for those struggling to start a family or who feel they haven't met the right person in time, says Robin Hadley who studied involuntary childlessness in older men at Keele University, UK.

For all the men like my father who do become parents later in life, there are increasing numbers of couples who won't be able to have the family they so desperately want. Until male infertility is taken as seriously as women's, that will only get worse. "We think that we are the most advanced species on Earth, and now many couples are unable to conceive naturally. It's unbelievable," says Levine. "I hope that we can do something to pay more attention to male fertility, but the correct approach would be to look at the fertility of couples. It's more complicated, but that's life - and I'm optimistic that once we recognise the problem, we will find solutions." ■

Moya Sarnier is a freelance writer based in London

D850



David I AM RELENTLESS



DAVID YARROW INTRODUCES THE NEW NIKON FULL FRAME D850.

To launch the new Nikon D850, master wildlife photographer David Yarrow was given the creative freedom to capture the image of his lifetime, shot on the new D850. Thanks to the powerful combination of the 45.7MP FX format back-side illuminated CMOS sensor and the speed of 9*fps shooting, he could tell a story like never before. With ISO 64 to 25600, 153-point AF, 8K time-lapse** and full frame 4K UHD video, now you too can capture your masterpiece. David is passionate about wildlife conservation, and is the affiliated photographer of the Tusk Trust Foundation. To find out more about the D850, and David's story, follow Nikon on Facebook and YouTube.

*Requires the optional MB-D18 Multi-Power Battery Pack, EN-EL18a/b battery, BL-5 battery cover and MH-26a charger. **Requires Interval Timer settings and 3rd party software.

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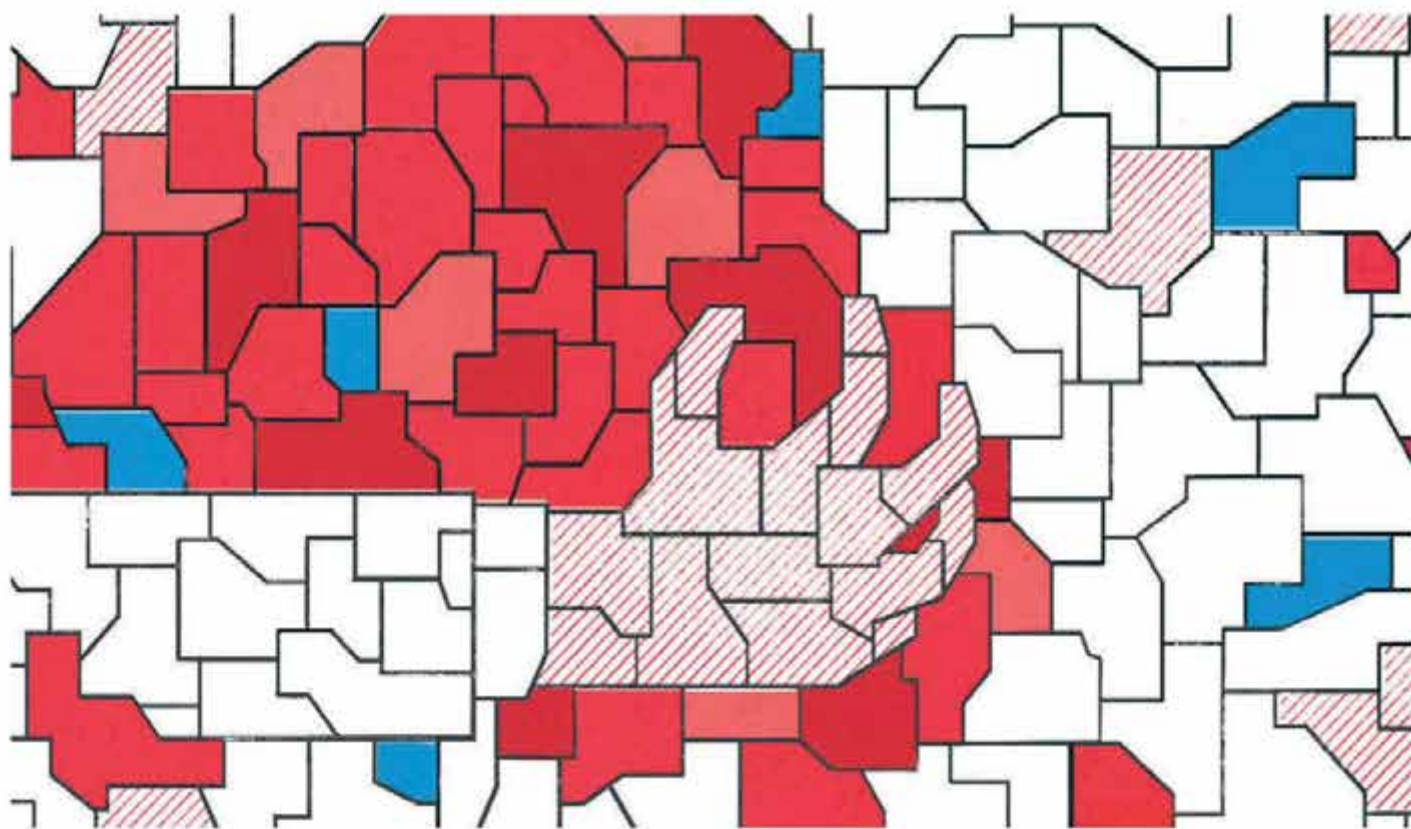
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Something is rotten in the states

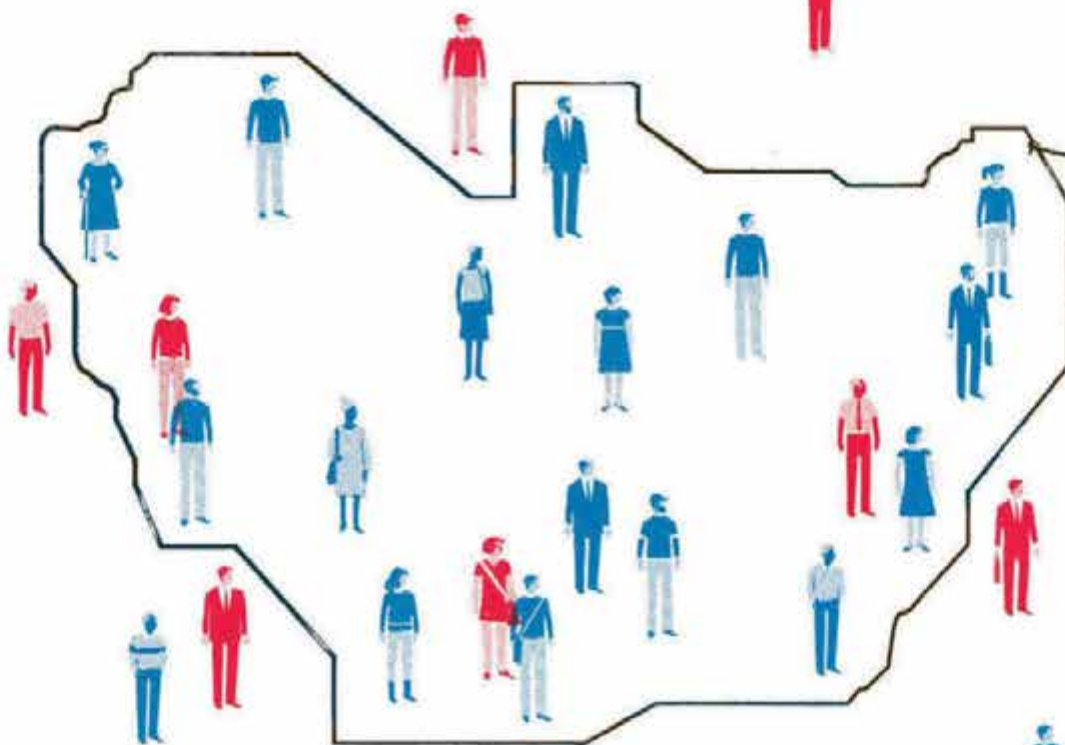
Gerrymandering can undermine the democratic process.
A mathematical solution could be at hand, says **Timothy Revell**

THIS time next year, US voters will be picking over the results of the 2018 mid-term elections. Will a beleaguered President Trump see the Republican majority harden in a further swing to the right? Or will the Democrats sweep to power in Congress and thwart his agenda?

It all comes down to where the votes are on the map – and how much they count for. Because in a “winner takes all” electoral

system like that in the US and the UK, not all votes are created equal. You might be living in an area that’s a shoo-in for one party – meaning whether you support it or don’t, your vote is superfluous as far as the final result is concerned. Conversely, the electoral division you live in might be on a knife edge, giving disproportionate weight to the small number of votes that can tip the balance. That means the boundaries between seats matter, too.

Gerrymandering – the drawing of electoral boundaries to benefit one party or group – is currently a hot political topic in the US, where the Supreme Court is considering a landmark case on the practice. In the UK, supposedly non-partisan boundary commissions are soon to propose what could be the biggest redrawing of its electoral map since the 1920s. So can boundaries ever be drawn fairly? And what exactly does fairness mean? To answer ►



these questions, we need to put mathematics at the heart of politics.

Underpinning the democratic process is the notion that all votes should count equally: if it takes 1000 voters to elect a representative in one district, for example, it shouldn't take 100 to elect another. It's an admirable goal, and one of the reasons that regular censuses form an important part of democratic life.

But even within congressional or parliamentary districts of similar size, a single vote doesn't always carry the same weight. The inordinate value of a few votes in finely balanced districts is exacerbated in winner-takes-all systems, where a candidate can represent nearly half the voters but still lose out by one or two percentage points.

This is the system used for parliamentary elections in the UK, as well as across the US (with the exception of a handful of state legislatures and the notoriously convoluted presidential elections). In both countries, a party can accumulate millions of votes and still secure no representation. "The most reasonable thing to do would be to abolish the system and start again," says mathematician Peter Gritzmann at the Technical University of Munich, Germany.

But that's not going to happen any time soon, and even if it did, there's no perfect voting system to take its place.

In the UK, at least, politicians generally don't get to decide the electoral maps (see "Splintered Isle", page 39). In the US, although a couple of states have handed over "redistricting" powers to an independent commission, those in power across most of the country have almost total freedom to redesign the maps. And redesign them they do. Republicans and Democrats are both guilty of gerrymandering, despite both sides agreeing that it's wrong. The problem is that spotting the practice is tricky, and proving it even trickier.

The classic technique to hijack an election is called packing and cracking: a gerrymanderer tries to create a small number of districts packed with their opponent's voters, and draws other seats to spread the remaining vote so there isn't quite enough for a majority. This results in their opponent winning a few seats with thumping majorities, while narrowly losing many more (see "Divide and rule", right).

Packing and cracking has been used along party, racial and religious lines all over the

world. In the US, racial gerrymandering in particular – the redistribution of African American or Hispanic voters so as to curb their influence – was so widespread that the government was forced to step in and outlaw it. The Voting Rights Act of 1965 protected the rights of minority citizens to have their voices heard, effectively institutionalising a form of benign gerrymandering to protect their ability to elect a representative of their choice.

"Voters don't choose their elected officials. Elected officials choose voters"

But when political affiliation is at play in drawing electoral boundaries, the courts have been effectively toothless. The result is that voters don't choose their elected officials; instead, elected officials choose their voters.

With advances in technology over the years, it is now possible to quickly assess thousands of possible electoral maps and their impact. Worried you are just not hitting it with the younger generation? Press a few buttons and moments later, you can have hundreds of



maps that satisfy all of the legal requirements, while also packing or cracking the youth vote.

The case now being considered by the US Supreme Court has its roots in a redrawing of the electoral map of Wisconsin by Republican legislators in 2011. The benefit to their party was obvious, as a year later they won 60 per cent of the seats in the Wisconsin State Assembly with less than half the overall vote – a significantly improved result. When they repeated this feat at the 2014 elections, a group of Democrat voters sued. Nearly every similar lawsuit had failed, but surprisingly this group won. In November 2016, the state's federal court in Madison said that the maps were so biased that they violated the constitutional rights of Democrat voters.

But what does fairness look like? For most people, a natural definition looks a lot like proportional representation, where the percentage of votes a party gets aligns with its share of seats. But that's not the intent of a winner-takes-all system, where non-proportional results are part of the furniture. Somewhere like Massachusetts, for example, has a solid Democrat majority spread evenly across the state – so all nine members returned to the US House of Representatives

are Democrats. “Even if you tried to gerrymander Massachusetts in favour of Republicans, it would be extremely hard,” says Mira Bernstein, a mathematician at Tufts University in Medford, near Boston.

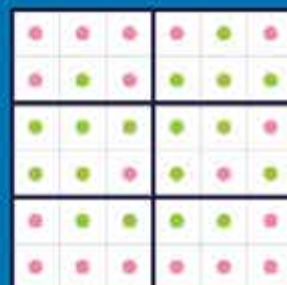
The Supreme Court has previously ruled that proportional representation is not guaranteed by the constitution, ruling it out as a way of defining “fair” boundaries. “This does not prevent us from finding a good mathematical test for gerrymandering, but it does mean that such a test will be hard for most people to grasp,” says Bernstein.

One test will be obvious to anybody who has ever seen a gerrymandered district: it looks funny. This is hinted at by the word “gerrymander” itself, coined after the 1812 redistricting plan of Massachusetts governor Elbridge Gerry, whose redrawn maps included one notorious district shaped like a salamander. Ever since, mathematicians have tried to craft some measure that would reveal when a district was too weirdly shaped to be anything but the product of a political agenda to play.

Such “compactness metrics” sound good in theory. The trouble starts when you try to quantify what it is that makes one shape ➤

Divide and rule

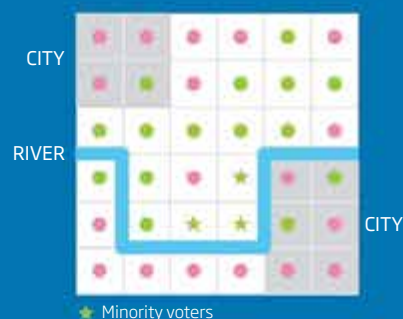
Imagine 36 voters, half supporting the **pink party** and the other half the **green party**. Keeping the districts the same size ensures each vote counts equally. Sometimes, simple divisions produce fair results



Election result

3 pink & 3 green representatives

Geographical features such as rivers or coherent entities such as cities generally prevent such simple solutions. To protect the voting rights of minority groups, US law also allows the creation of districts where they form a majority



Divisions that take these realities into account can skew results in one party's favour, as below, where the greens are a minority in most districts. If boundaries are deliberately shifted to favour one party then we have **gerrymandering**

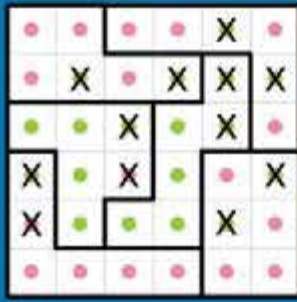


Election result

4 pink & 2 green representatives

How to spot a gerrymander

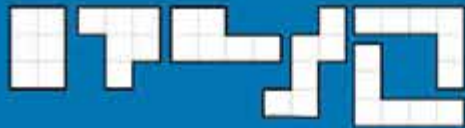
Tests to detect gerrymandering involve measuring the fairness of political boundaries. The **efficiency gap**, for instance, compares each party's number of wasted votes. In this example, a party needs four votes to win a seat in each district, so all other votes in that area are wasted



X Wasted pink votes	2
X Wasted green votes	10
Efficiency gap	8

Another way to check for gerrymandering is to use a geometric test such as **isoperimetry** or **convexity**. Essentially, these both work the same way: the odder the shape of an electoral unit, the greater the chance that it was intentionally drawn to favour one party

Isoperimetry:
How efficiently the perimeter encloses the area



Increasing unfairness →



Convexity:
Tie a rubber band around a shape. The less additional area enclosed, the better

But no test is perfect. Geometric tests can't distinguish between districts that are a funny shape because of restrictions imposed by roads, rivers or city boundaries and those designed for political gain. And the efficiency gap struggles to produce meaningful results when one party dominates

weirder than another. For some, the key property to test is isoperimetry, a measure of how efficiently a perimeter encloses the area within. By this yardstick, circles are maximally compact while long, snaking salamander shapes are not very compact at all. The logic starts to fall apart, however, when we confront the issue of how to measure a perimeter. Do you go around the boundaries of the district measuring distances down to the nearest kilometre? Centimetre? Nanometre? The smaller your ruler, the more imperfections you'll be able to measure. Rather than a simple polygon consisting of a handful of straight lines, you could end up with a jagged shape of almost infinite perimeter.

A simpler version of the test measures convexity, or how closely the district's area matches that created by placing a giant elastic band around it. Squares and rectangles? Very convex. Crescent moons and spiky polygons? Not so good.

Tests like convexity, or more sophisticated ones such as curvature, which take into account how a district's residents are spread within it, are a step in the right direction. But ultimately, they fall at a crucial hurdle. Sometimes, districts just need to be a funny shape. Highways, rivers, mountain ranges and city boundaries all impose real constraints on map-makers, and can result in shapes no less weird than Gerry's salamander for reasons that are perfectly noble. The 4th district in the state of Illinois, for example, is sometimes known as the "earmuffs" because of its distinctive shape. But to the two Hispanic communities it connects, the earmuffs offer them a hard-won constitutional right to decide on their own representative. Geometry alone would leave them vulnerable.

In 2014, Nicholas Stephanopoulos of the University of Chicago Law School and Eric McGhee of the Public Policy Institute of California developed an alternative test. Called the efficiency gap, it's a simple way to hunt for signs of packing and cracking, and has accompanied the Wisconsin case all the way to the Supreme Court.

The efficiency gap is based around counting wasted votes for all political parties, a wasted vote being one that doesn't contribute to electing a representative. So for example, all of a losing party's votes are wasted, as are any of a winning party's votes that it didn't need for victory. Every system will have wasted votes, but if one party is wasting substantially fewer than another, it's a sign gerrymandering could be afoot (see "How to spot a gerrymander", left).



PAUL ELIS/GETTY

In Wisconsin, the efficiency gap was 13 per cent in favour of the Republicans, three times the average across the country. The lawyers in the original court case argued that anything over 8 per cent should be considered unconstitutional, and are hoping the Supreme Court approves their logic.

Fairest of them all?

The efficiency gap is a simple metric that may go on to shape the future of US democracy. But it's not without its drawbacks. It turns a blind eye to gerrymandering committed by both parties, for example, so long as they offend equally, and struggles to produce meaningful results when one party has a genuinely dominant majority. For some, the efficiency gap also fails because it assumes that voters are entitled to a specific relationship between vote share and representation. "There is absolutely no reason to think that this, or any other, relationship is mandated by the constitution," says Bernstein.



SPLINTERED ISLE

Reviews of the UK's electoral map happen periodically, but what makes next year's so significant is that the new map will do away with 50 constituencies, lowering the total to 600. Unlike the situation in the US (see main story), the map will be redrawn by independent boundary commissions rather than politicians. Their focus is meant to be exclusively on drawing up districts of equal size, and the guidelines prohibit them from considering the political implication of their choices.

Anyone can suggest improvements once the proposed map is published, but the commissions are under no obligation to accept them. "This is the nearest we have to gerrymandering in the UK," says Ron Johnston at the University of Bristol.

When the proposed changes begin to emerge, there will no doubt be allegations of gerrymandering, with Labour, the largest opposition party, especially likely to complain. "Since World War II, the trend in the UK has been for people to move away from inner cities, where there are more Labour voters, and into suburbs,

where there are more Conservative voters," says Charles Pattie at the University of Sheffield. This means that Conservative constituencies tend to grow more populous, and so more votes are needed to elect a Conservative member of parliament. For Labour, the reverse tends to happen, meaning they get more bang for their buck.

Holding periodic boundary reviews readdresses this imbalance. "There is a strong case for saying that the only way in which parties can 'guarantee' a gerrymander in the UK is by not holding boundary reviews," says Pattie.

But the fragile nature of the present minority Conservative government could lead to the latest review being mothballed. The Conservatives are reliant on the Northern Irish Democratic Unionist party to get their legislation through parliament, and the DUP are unlikely to back any vote that would reduce the number of representatives for Northern Ireland, as that could in turn weaken their influence on national politics.

One way of distinguishing between natural and deliberate gerrymandering is to use the ability of computer simulations to generate thousands of different maps. A group at Duke University in Durham, North Carolina, recently used an algorithm to randomly draw 20,000 possible electoral maps for Wisconsin that satisfied all of the required criteria laid down in US law. In most of these, the Republicans won a majority, making it seem like the Democrats were just at a natural disadvantage.

But in the majority of the maps, Republicans secured a narrow advantage, replicating their 2014 margin of victory only in a very small number of maps. This means that the Wisconsin electoral map is a clear outlier and therefore is likely to have been gerrymandered. For mathematicians like Bernstein who worked on the algorithm, this statistical analysis is vitally important yet has been largely ignored in favour of the efficiency gap. "Fortunately," says Bernstein, "the justices did notice, and they

are the ones who matter."

"If the court rules the Wisconsin map unconstitutional under a particular test," says Joshua Douglas at the University of Kentucky, "then that will place an outer limit on the worst abuses in partisan gerrymandering." This would have the biggest effects in swing states such as Wisconsin, North Carolina and Maryland. "The ruling would ultimately produce fairer maps, which also will likely give average Americans more confidence in the election process," says Douglas.

Though the Supreme Court case has heard arguments from both sides, it will probably be months until it reaches a decision. Should it uphold the lower court's decision, then the impact will be far-reaching. When states redraw their districts after the 2020 census, they may have to take account of the efficiency gap test, which many of them fail at present.

"The proposal allows for map-makers to break the efficiency gap requirement in

exceptional cases, provided they offer sufficient justification," says mathematician Dustin Mixon at Ohio State University. But they may just start taking the efficiency gap into their calculations to try to find another way to exploit the system, albeit in subtler ways. "This could in turn incentivise bizarrely shaped districts," he says.

And while a rigorous mathematical test for gerrymandering will help level the playing field, and may even give Democrats an edge in the next few elections, it is unlikely to help the US overcome its partisan divides. Those with strong political views tend to vote with their feet, moving to live near those who hold the same opinions. Democrats cluster in cities, while Republicans dominate surrounding districts. At the end of the day, the problems pulling American society apart arise when people start gerrymandering themselves. ■

Timothy Revell is a technology writer at *New Scientist*

Delusional you

We live in an age of mass delusion and very few of us are immune, finds Dan Jones

THREE Messiahs walk into a psychiatric unit... No, this isn't the set-up to a tasteless joke, but the beginning of a study done in the 1950s by Milton Rokeach at Ypsilanti State Hospital, Michigan. Rokeach brought together three men, each harbouring the delusion that he was Jesus Christ, to see if meeting the others and confronting their mutually contradictory claims would change their minds. Two years and many arguments later, their beliefs had barely budged. For each Jesus, the other two were fakers, while they were the real deal.

As delusions go, the Messiah complex is extreme. Most delusions are far more mundane, such as an unfounded belief that you are exceptionally talented, that people are out to get you or that a celebrity is in love with you. In fact, more than 90 per cent of us hold delusional beliefs. You may find that figure shockingly high – or perhaps you see evidence all around, in the willingness of so many people to swallow fake news, in the antics of politicians and celebrities, and even among your Facebook friends. Either way, what exactly does it mean? Why are some of us more prone to delusions than others? How do false beliefs get a hold in our minds? And can we all learn to tame our delusional tendencies?

First we need to be clear about what a delusion is. “There’s a loose way of talking about delusions – like when we talk about the ‘God delusion’ – which simply means any belief that’s likely to be false and is held despite lack of evidence, or even in spite of the evidence,” says Lisa Bortolotti at the University of Birmingham, UK. The psychological take is more nuanced. Delusions are still seen as irrational, but they are also

idiosyncratic, meaning the belief is not widely shared. That rules out lots of things including most religious beliefs, conspiracy theories and the denial of climate change. Furthermore, the idiosyncratic nature of delusions makes them isolating and alienating in a way that believing, say, a conspiracy theory is not. Delusions also tend to be much more personal than other irrational beliefs, and they usually conform to one of a handful of themes (see “What’s your delusion?”, page 42).

Bizarre beliefs

At any time, around 0.2 per cent of people are being treated for delusional disorders. We now know that this is the tip of an iceberg. In 2010, Rachel Pechey and Peter Halligan, both at Cardiff University, UK, presented 1000 people with 17 delusion-like beliefs, and asked whether they held them strongly, moderately, weakly or not at all. The beliefs were either relatively mundane, such as “Certain people are out to harm me” and “I am an exceptionally gifted person that others do not recognise”, or more bizarre, including “I am dead and/or do not exist” and “People I know disguise themselves as others to manipulate or influence me”. In all, 39 per cent of participants held at least one of these beliefs strongly, and a whopping 91 per cent held one or more at least weakly. What’s more, three-quarters of people subscribed to bizarre beliefs to at least some extent.

“Symptoms of psychosis-like delusions are just the extreme end of a continuum of similar phenomena in the general population,” says Ryan McKay at Royal Holloway, University of London. More

evidence for this comes from the Peters Delusion Inventory, which is frequently used to measure how prone people are to delusional thinking. The inventory asks respondents whether or not they have ever experienced various different beliefs that often crop up in a clinical context, resulting in a delusion-proneness range from 0 to 21 (see “How deluded are you?”, page 43). Among the general population, people score an average of 6.7, with no difference between men and women. People with psychotic delusions score about twice this. So they do have more of these beliefs, but what really sets them apart from others is that they tend to be more preoccupied with their delusional beliefs and more distressed by them. “It’s not what you think, it’s the way that you think about it,” says Emmanuelle Peters of King’s College London, who led the development of the inventory.

That we are all prone to delusions may not be so surprising. A range of cognitive biases makes the human mind fertile soil for growing all kinds of irrational beliefs. Confirmation bias, for example, means we ignore inconvenient facts that go against our beliefs and uncritically accept anything that supports them. Desirability bias leaves us prone to shoring up beliefs we have a vested interest in maintaining because they make us or our group look good. Clustering bias refers to our tendency to see phantom patterns in random events, impairing our ability to draw logical conclusions from the available evidence.

A quick trawl of social media is all it takes to see how these utterly human ways of thinking can contribute to a cornucopia of strange and idiosyncratic beliefs. But the question of why some of us are more delusion prone than



Do you ever feel as if you
have been chosen by God
in some way?

JONAS BECKEN/MAGNUM PHOTOS

STRANGE BELIEFS

Despite being diverse and idiosyncratic, delusions cluster into a few core themes.

PERSECUTORY DELUSIONS:

beliefs that others are out to harm you. This is the most common type of delusion, affecting between 10 and 15 per cent of people.

REFERENTIAL DELUSIONS:

beliefs that things happening in the world – from news headlines to song lyrics – relate directly to you. Persecutory and referential delusions often go hand in hand.

CONTROL DELUSIONS:

beliefs that your thoughts or behaviours are being manipulated by outside agents. Such delusions are common in schizophrenia.

EROTOMANIC DELUSIONS:

beliefs that someone who you don't know, typically a celebrity, is in love with you.

GRANDIOSE DELUSIONS:

unfounded beliefs that you are exceptionally talented, insightful or otherwise better than the hoi polloi.

JEALOUS DELUSIONS:

irrational beliefs that your partner is being unfaithful. This is the type of delusion most commonly associated with violence.

SOMATIC DELUSIONS:

erroneous beliefs about the body. In Ekbom's syndrome, people believe they are infested with parasites. People with Cotard delusion believe they are dead or don't exist.

MISIDENTIFICATION DELUSIONS:

beliefs about changed identity. A classic is Capgras delusion, where people believe that a loved one has been replaced by a doppelgänger.

others is more difficult to answer.

It could have something to do with how we see the world – literally. In one study, volunteers watched an optical illusion consisting of a set of moving dots that could either be perceived as rotating clockwise or anticlockwise. The dots seemed to periodically flip direction, in much the same way a Necker cube changes its orientation as you look at it. Those individuals who scored highly on delusion-proneness perceived the dots as switching direction more frequently, suggesting they have a less stable perceptual experience. How this influences thinking remains unclear, but it doesn't end there. Participants then wore glasses, which they were told would make the dots appear to rotate one way rather than the other. In reality, the glasses had no effect, but delusion-prone people reported seeing the dots move in the supposed biased direction – a case of seeing what you believe. Another recent study revealed that their perception of time is distorted, too. Delusion-prone people were more likely to believe they had predicted events they could not have because of the order they happened in, indicating that they were making mistakes in judging the temporal order of their thoughts.

It is tempting to conclude that people susceptible to delusional thinking are more suggestible than others, but another study designed to test this explicitly found the opposite. In fact, delusions don't typically

“Do you ever feel that things in magazines were written especially for you?”

start out as an idea seeded by someone else, but from a strange or anomalous experience generated by ourselves. The crucial second step in forming a delusion is that the person then invents an explanation for this experience. People with Capgras delusion, for example, explain a disturbing feeling of disconnection from a loved one by concluding that he or she has been replaced by a doppelgänger or hyper-realistic robot. This implies some kind of problem with evaluating the plausibility of one's beliefs, says McKay. In Capgras, it has been linked to damage in specific brain networks. However, there is a more everyday reason that people hold implausible beliefs: a tendency to jump to conclusions on the basis of limited evidence.

The extent to which anyone does this can be

measured with a simple experiment. Imagine two jars containing a mix of black and orange beads: one contains 85 per cent black beads and 15 per cent orange, and the other has the reverse proportions. You select a bead from one, without knowing which it is. Let's say the bead is orange. You are then asked whether you would like to make a call on which jar you are taking beads from, or whether you want to draw another bead to help work it out. It is prudent to examine a few beads at least – it is quite possible to draw two orange beads from a jar with mostly black, and vice versa. Yet, around 70 per cent of people being treated for a delusion make a judgement after seeing just one or two beads. Only 10 per cent of the general population are as quick to jump to conclusions, but the more prone you are to delusional thinking, the fewer beads you are likely to sample before making your decision.

This jumping-to-conclusions bias might seem stupid, but it isn't a sign of low intelligence, according to clinical psychologist Philippa Garety at King's College London. Instead, she believes it reflects the kind of reasoning an individual favours. Some of us rely more on intuitive thinking – so-called system one thinking – while others are more likely to engage slower, analytic “system two thinking”, which is needed for reviewing and revising beliefs. In a recent study, Garety's team found that the less analytical a person's style of thinking, the fewer beads they wanted to see before making a judgement. “It's not that people with a jumping-to-conclusions bias don't understand or can't use evidence,” she says. “They're just overusing system one at the expense of system two.” And sure enough, Garety's latest study confirms that these intuitive thinkers are also more prone to clinical delusions.

It looks like a vulnerability to delusions is part and parcel of regular human psychology. After all, everyone is an intuitive thinker at times: even people who favour system two thinking rely on quick, system one thinking when tired, stressed or scared. Whether humanity is becoming more deluded than ever is another question. In today's hyper-mediated world, we are continually exposed to new experiences and people, and called upon to evaluate all sorts of beliefs that our forebears wouldn't have encountered. We may also be more tired and stressed. As a result, it is possible we have more numerous or richer delusions than past generations. Nobody has done the research. But even if that is the case, this may have some advantages. “Delusions can be helpful when they make people feel



Do you ever feel as if your thoughts were being echoed back to you?

good about themselves or explain aspects of their life that are difficult to understand,” says Bortolotti. It can be empowering to feel that a celebrity is in love with you, for example. And there is plenty of evidence that an inflated belief in your talents can have all sorts of benefits, from success in job interviews to attracting a sexual partner.

Alternatively, our alarming susceptibility to fake news and the outlandish behaviour of key players on the world stage might lead you to conclude that we could do with a bit less delusional thinking. If so, the good news is that insights into delusion psychology point to some ways we can curb it. Garety has helped design an intervention to train people’s slow-thinking skills. SlowMo, which includes therapy and an app, is intended for people with paranoid delusions, but it nurtures mental habits all of us can benefit from. They include gathering sufficient data before making conclusions, learning to question your initial thoughts and impressions about events, and considering different explanations of experiences. SlowMo is currently being tested. If it proves effective, the app will be available in the UK through the National Health Service.

HOW DELUDED ARE YOU?

Almost everyone is vulnerable to delusions, but some of us more than others. These 21 questions constitute the Peters Delusion Inventory, which is the most widely used measure of delusion proneness. Give yourself one point for each “yes” and zero points for each “no”, then tot up your score.

- 1 Do you ever feel as if people seem to drop hints about you or say things with a double meaning?
- 2 Do you ever feel as if things in magazines or on TV were written especially for you?
- 3 Do you ever feel as if some people are not what they seem to be?
- 4 Do you ever feel as if you are being persecuted in some way?
- 5 Do you ever feel as if there is a conspiracy against you?
- 6 Do you ever feel as if you are, or destined to be someone very important?
- 7 Do you ever feel that you are a very special or unusual person?
- 8 Do you ever feel that you are especially close to God?
- 9 Do you ever think people can communicate telepathically?
- 10 Do you ever feel as if electrical devices such as computers can influence the way you think?
- 11 Do you ever feel as if you have been chosen by God in some way?
- 12 Do you believe in the power of witchcraft, voodoo or the occult?
- 13 Are you often worried that your partner may be unfaithful?
- 14 Do you ever feel that you have sinned more than the average person?
- 15 Do you ever feel that people look at you oddly because of your appearance?
- 16 Do you ever feel as if you had no thoughts in your head at all?
- 17 Do you ever feel as if the world is about to end?
- 18 Do your thoughts ever feel alien to you in some way?
- 19 Have your thoughts ever been so vivid that you were worried other people would hear them?
- 20 Do you ever feel as if your own thoughts were being echoed back to you?
- 21 Do you ever feel as if you are a robot or zombie without a will of your own?

1-5 You are less prone to delusions than most. Your thinking style is probably more analytical than intuitive. 6-7 Congratulations! You are normal. The average score is 6.7, with no difference between men and women. 8-21 You are more prone to delusions than most. You are likely to think intuitively and jump to conclusions.

SCHIZOPHRENIA BULLETIN

Changing your mind

Of course, changing the way you think isn’t easy. It takes effort, and support. “There’s some evidence that people who have good relationships at home and have someone to talk to are more able to activate slow thinking,” says Garety. Even if that’s not your goal, sharing your thoughts is a good first step to dispelling delusions. “It’s psychologically healthy to recognise that our thoughts sometimes need inspection and engagement with the world to assess how right they are,” says clinical psychologist Daniel Freeman at the University of Oxford.

Simply talking can highlight delusional thoughts in ourselves and others. But then what? We know that delusions are impervious to counterargument. In fact, trying to disprove them can backfire. Freeman has some advice based on his clinical work. First, provide a plausible, non-threatening alternative perspective. Then, help the deluded person gain evidence that bolsters this perspective.

“We don’t try to disprove people’s beliefs,” he says, “because we know that has the opposite effect, just like when people argue in a pub – no one changes their mind.” If you don’t believe him, ask any Jesus Christ. ■

Dan Jones is a freelance writer based in Brighton, UK

The original batman

Lazzaro Spallanzani was the first to unravel the mystery of how bats could “see” and hunt in total darkness, with some ingenious, if gruesome, experiments

LAZZARO SPALLANZANI watched by the flickering light of a single candle as a bat flew hither and yon around his simple room in Reggio nell’Emilia, Italy. Then he made a remarkable observation: when he blew out the candle, the bat’s flight was unaffected. It flew in total darkness as if it were light! Spallanzani, an ordained Catholic priest and tireless, self-taught scientist, knew this because he had tied some string around one of the bat’s bony ankles. Holding tightly to it like a strange kite, he occasionally felt the bat tugging in different directions as it flew around in the pitch-black room. When he repeated the test with his tame barn owl – or “night-bird”, as he called it – the owl became clumsy in total darkness. It flew into the walls. It collided gracefully with objects in the room.

How was the bat different to the owl? With this simple question in 1793, Spallanzani began an ingenious series of experiments that still hold up today – in terms of rigour, if not ethics. His studies might have been revolutionary, if everyone had known about them. Instead, most of the work went unpublished. It was sent in letters to correspondents. Other findings he committed to notebooks, unread until the 1940s. Instead, it would take another century and a half from the time of his discovery for researchers to uncover the complex system of echolocation that bats use to navigate.

Born in 1729, Spallanzani wrote widely about the natural world – about swallows, owls and eels. His interests seemed endless. He filled his notebooks with observations about reproduction, breathing and the maintenance of body temperature. He was

widely known as an expert on sperm. In one study, he proved that sperm is involved in frog reproduction by dressing male frogs in tight taffeta pants to prevent its release. He was so industrious that his contemporaries called him *Magnifico*. And as you might expect from any historical figure with such a nickname, he was zealous. For example, to better understand digestion, he swallowed little food-filled cheesecloth bags tied to string and, at regular intervals, hauled them up from his stomach to assess their contents.

Hello, flittermouse

But bats really fascinated him. Scientists knew little about bats when Spallanzani had them flying around his room. In 1758, Carl Linnaeus had only named a handful of bat species in the definitive tenth edition of *Systema Naturae*, his attempt to classify the natural world. He was the first person to separate bats and birds taxonomically. Today, there are more than 1300 known species. Diverse and highly adapted, they are found on every continent except Antarctica. But in 1793, people still argued about whether bats had more in common with mice or birds. In the Roman era, Pliny had placed them with birds, an error with a long life. Linnaeus made the correction, but some ideas die slowly.

In Spallanzani’s day, bats were also known as flittermice. Some people thought the only thing a flittermouse was good for was curing gout and leprosy. As *Zoologia Medicinalis Hibernica*, a medical textbook published earlier that century, put it: “Bat, or Flittermouse, The flesh of a bat medicinally taken, is good

against a scirrhus of the liver, the gout, rheumatism, cancer, and leprosy.”

But Spallanzani’s mind was alert to the simple mystery that eluded others. How does a bat navigate in the dark? At first, he approached the subject gently. He covered a bat’s head with a tiny, opaque hood. Suddenly, it flew into the walls of his room like the owl would in his later experiment. This led him to the logical, though mistaken, idea that somewhere that looked dark to humans and owls had some mysterious luminescence, which a bat with no hood could see. “Thus a place which we believe to be completely dark is not so at all,” he wrote.

SPL: GUY THOMAS/ALAMY



To test this hypothesis, he covered bats' eyes with birdlime, a sticky substance that locals spread on trees to catch birds. This time, to his surprise, although the bats were effectively blinded, their navigation was unaffected. "These phenomena induced me to perform another experiment which I considered decisive," wrote Spallanzani in August 1793, "namely to remove the eyes of a bat." This excision duly done, he was stunned to find the bat could still navigate. "My astonishment at this bat, which absolutely could see although deprived of its eyes, is inexpressible," Spallanzani wrote.

Around the same time, a researcher called

Charles Jurine in Geneva, inspired by his correspondence with Spallanzani, was plugging bats' ears with grease. He observed that their flight was impaired. It was becoming clear that the bats must be using their ears to find their way. Spallanzani's hooded bats had been unable to hear properly; that they couldn't see was less important. Ultimately, Spallanzani devised an elegant experiment to resolve the question once and for all. He made two small, cone-shaped tubes from brass and fixed them carefully in a bat's ears. With the cones in place, the animal flew unaffected. "When I closed the tubes with pitch so that the air could no longer enter the auditory duct, the

animal did not fly at all, or its flights were short and uncertain, and it frequently fell."

In the summer of 1794, Spallanzani took his exploration of bats' abilities to another level – literally. In the bell tower of the cathedral in Pavia, he swept a net through the air, retrieving bats from its recesses. In one day, he caught 52 specimens, probably all greater mouse-eared bats (*Myotis myotis*). A few minutes later, in the shadow of the campanile, still dressed in his vestments, he removed the eyes of the bats and released them. Four days later he returned. This time he caught 48 bats. He'd captured three of them before: they had no eyes. When he opened their stomachs, he found them filled with insects. Finally, there was no doubt. Even blind bats could navigate, hunt and survive as long as they had their hearing.

"My astonishment at this bat, which can see without eyes, is inexpressible"

Fast-forward to 1938. Donald Griffin is a student at Harvard University. For his studies, he is placing numbered tags around the ankles of different species to aid the tracking of their seasonal migrations. Collaborating with Robert Galambos, who worked in the emerging field of auditory physiology, Griffin gained access to an early version of an ultrasonic detector. In a darkened laboratory, the pair ran a series of studies as elegant as Spallanzani's – if less gruesome. Finally, with the modern apparatus, they were able to hear the staccato ultrasonic vocalisations that bats emit and bounce off their surroundings. And they showed that bats could use them to dodge obstacles – right down to thin wires – even in the dark. Griffin understood immediately that bats generate a 3D picture of their environment based on the way their vocalisations bounce back to them.

But it was Spallanzani, crouched in the darkness in 1793 with a string tied to a bat's leg, who made the key breakthrough. It was Magnifico, high above Pavia in the darkness of a bell tower, who first discovered the truth about bats. Luckily for him, the poor flittermouse never heard him coming. ■

Christopher Kemp's new book is *The Lost Species: Great expeditions in the collections of natural history museums* (University of Chicago Press)

The master decoders

A wide-ranging exhibition celebrates two geniuses, one who broke Nazi codes, the other who cracked an ancient script.

Andrew Robinson explores an unusual pairing

Codebreakers and Groundbreakers, Fitzwilliam Museum, Cambridge, to 4 February 2018

IF YOU had to guess the most indecipherable object in an exhibition about mathematics, codes, linguistics and archaeology, what would it be? The keyboard, plugboard and rotors of the 1940s Enigma electromechanical cipher machine used by German U-boat commanders? Or one of the ancient Linear B clay tablets excavated at Knossos in Crete, inscribed with recognisable numerals and part-pictographic signs such as animal heads, handled cups and chariot wheels?

No, the most mysterious object at the Fitzwilliam Museum's unprecedented pairing, *Codebreakers and Groundbreakers*, has no symbols.

It is a plain, slightly battered, silver teaspoon belonging to one of the two stars of the show, Alan Turing. The teaspoon was lent by King's College, Cambridge, where Turing was a student and a fellow in mathematics. He was to become the UK's best-known wartime codebreaker at Bletchley Park – and recognised as a pioneer of computing.

The teaspoon, never before seen in public, carries a paper label handwritten and signed by Turing's mother. Sara Turing writes that "This is the spoon which I found in Alan's laboratory", soon after her son's untimely death.

Cracked: the wartime Enigma electromechanical cipher machine

She adds: "It is similar to the one which he gold-plated himself. It seems quite probable he was intending to gold-plate this one using cyanide of potassium of his own manufacture."

Turing unquestionably died from cyanide poisoning in Manchester, UK, in 1954, aged

"Scripts are in principle readable by anyone trained in writing the underlying language"

just 41. But to this day, no one knows how he really died, despite informed speculation, including that of his biographer, mathematician Andrew Hodges, and of the 2014 Turing biopic, *The Imitation Game*.



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Was it a home-lab accident, as his mother maintained? Or was it suicide, as the inquest concluded, perhaps provoked by Turing's 1952 conviction for "gross indecency" at a time when homosexual acts were still illegal, and he was feeling the disturbing effects of opting for hormonal treatment with oestrogen in order to avoid prison. These led Turing to tell a male mathematician friend: "I'm growing breasts!"

By strange coincidence, doubt also obscures the death of the show's other star – Michael Ventris, the man who deciphered Linear B in 1952. He died in 1956, aged 34, in a car crash, while driving alone late at night near London.

Although Ventris had depression – provoked by disappointment with his lack of artistic ability as a professional architect – the inquest declared the crash an accident. Again, what really happened remains unclear, despite the research efforts behind 2002 BBC TV drama-documentary *A Very English Genius*.

As for their research, Ventris and Turing were both working on scripts: Linear B and codes such as Enigma are both forms of writing, though separated by more than three millennia. "There is an obvious resemblance between an unreadable script and a secret code; similar methods can be employed to break both," wrote Ventris's close collaborator John Chadwick, a classicist at the University of Cambridge, in *The Decipherment of Linear B*, published soon after Ventris's death. Chadwick once confessed to Ventris that he



was "the pedestrian Dr Watson" to the master decipherer's Sherlock Holmes.

Chadwick could not say so in *The Decipherment of Linear B* in 1958, but he had an inside track on Enigma: he had been one of a group of classicists at Bletchley working as wartime codebreakers who broke Italian and Japanese codes.

Yet there are important differences between scripts and codes, even though the term "code" is sometimes loosely used for scripts such as Linear B and its still-undeciphered predecessor, Linear A. The most important is that scripts are in principle readable by anyone trained in writing the underlying language, while codes are designed to conceal their meaning from anyone who does not know the code's key, however well trained in the underlying language.

Moreover, decipherers of a script have the advantage of being able to analyse the repeated



Iconic: one of the ancient Linear B clay tablets excavated at Knossos

patterns that inevitably occur in writing a natural language, but codebreakers cannot rely on such giveaway patterns, which are intentionally distorted during encryption.

Ventris's breakthrough was based on an inspired guess about such a pattern, on display in one of his fascinating letters – to a senior University of Oxford scholar in February 1952. This is immaculately written in English and Linear B.

In it, he guesses that a pattern of three similar, but not identical, Linear B sign-groups – spotted by a US classicist, Alice Kober, and dubbed “Kober’s triplets” by Ventris – might represent Cretan towns and their inhabitants. For instance, one triplet might translate as “Knossos” + “men of Knossos” + “women of Knossos”.

Decipherers are at a disadvantage because, unlike the majority of codebreakers, they usually do not know a script’s underlying

language. This explains why no one knew that Linear B was written in an archaic dialect of ancient Greek. Until his breakthrough in 1952, Ventris had backed a non-Indo-European language, Etruscan.

By contrast, Enigma messages could be safely assumed to encrypt German – although not necessarily the repeated sign-off “Heil Hitler!”, as *The Imitation Game* implies with full dramatic licence.

Turing and Ventris never met, nor were they aware of each other’s achievements in codebreaking and deciphering. Bletchley’s secrets, including Turing’s role, remained classified long after the founding of the A. M. Turing Award in 1966. Equally, Turing showed no interest in script decipherment, notwithstanding the worldwide publicity for Ventris and Linear B after 1952.

Turing was a specialist,

dedicated to mathematics and its applications from his teenage years, as the displays of his school report and pre-war papers on computing show. Ventris, on the other hand, did not shine academically and never went to university. But he had a considerably wider range of knowledge than Turing, not

“They were intellectually unconventional, personally modest and unusually willing to collaborate”

only in ancient and modern European languages, but also in architecture, art and archaeology.

What the two men shared, however, was intellectual unconventionality, personal modesty, an unusual willingness to collaborate with others – and general agreement among their peers about their respective status as geniuses.

Genius was surely at work in

Ventris’s guess about the Cretan place names. In that letter to the Oxford scholar, he admits that “This is one of those guesses it’s best to keep up one’s sleeve, because there’s an extremely good chance of it being completely wrong.”

The wide-ranging catalogue of this exhibition complements engaging interactive displays of wartime codes and Linear B inscriptions, designed to appeal to all ages. It contains 10 contributions by experts in Linear B, the history of cryptography and current methods of encryption, including Turing Award winner Tony Hoare at Microsoft Research.

And, in the epilogue, there is a tribute to Turing and Ventris by Cambridge philologist James Clackson. He says that in the popular imagination both men have become for the 20th century what Jean-François Champollion, the decipherer of Egyptian hieroglyphs, was for the 19th.

But Ventris’s achievement exceeds that of Champollion, who had the invaluable assistance of the Rosetta Stone, that world-famous chunk of dark grey granite-like stone which provided the key to deciphering ancient Egyptian writing. It was the first Ancient Egyptian/Greek bilingual text to be analysed in modern times, generating great public interest because of its potential to decipher an untranslated hieroglyphic language.

As Ventris noted in 1951 in one of the 20 work notes he circulated to would-be decipherers (the last of which is in the exhibition): “To wait for a bilingual to help us solve our problem is to cry for the moon.” ■

Andrew Robinson has written biographies of Jean-François Champollion (*Cracking the Egyptian Code*) and Michael Ventris (*The Man Who Deciphered Linear B*)

A place for good and evil?

What makes you a psychopath or an extreme altruist? **Clare Wilson** explores

The Fear Factor: How one emotion connects altruists, psychopaths, and everyone in-between by Abigail Marsh, Basic Books



THE clearest case of a budding psychopath that Abigail Marsh ever met was 12-year-old button-nosed Jamie. He stole, set fires, and ran a

profitable loan shark operation from his bedroom; when his schoolmates ran late with payments, he threatened to shoot fireworks at them.

Then there was 14-year-old Amber, who killed her pet guinea pig, shoplifted designer goods and threatened to burn down the house as her family slept. Marsh has scanned the brains of dozens of such children in a bid to understand what makes them tick. The most striking finding is that they have smaller and less active right amygdalas, a brain structure thought to let us feel fear and see it in others, as she recounts in *The Fear Factor*.

The fact that psychopaths fail to empathise with others' terror is old news. Before brain scanners were common, that could be shown just by asking them to identify pictures of fearful faces, a task they struggle with. Marsh quotes a psychopath in an English prison sitting such a test for a colleague: "I don't know what that expression is called – but I know that's what people look like right before I stab them."

The twist Marsh adds is to link this finding with her work on a

very different group of people: extreme altruists, who go to extraordinary lengths to help others. The most obvious examples are people who save others from burning buildings or freezing rivers. As a teenager, Marsh herself experienced such a rescue after a car accident late at night, an experience that helped motivate her research career.

Heroes are thin on the ground, though, so instead Marsh studied another kind of altruist: people who donate a kidney to a stranger. Many of us might consider giving a kidney to a relative, if we are healthy, but those who turn up at their nearest transplant hospital to offer their spare kidney to whoever is at the top of the list are a rarer breed. Marsh has found that this group has the opposite suite of traits to psychopaths: their right amygdalas are bigger and more active than most people's, and they are particularly good at recognising fearful faces, voices and body language.

You can probably see where this is going. Marsh's big idea is that humans vary in how kind they are to others, with psychopaths at one end of the spectrum, and extreme altruists at the other. And the key biological determinant of where you sit is your right amygdala, via how much it pains you to see or imagine others in distress.

It is a persuasive idea and one that Marsh provides some supporting evidence for, although

"Your place on the spectrum is shown via how much it pains you to see or imagine others in distress"

it seems a little too simplistic. It would have been nice to hear from her about the caveat that brain scanning studies may reveal correlation, not causation. In other words, perhaps the root cause of psychopathy is the malfunctioning of some other more complex and dispersed neural network, or perhaps

even that some people have underactive amygdalas because they underuse them.

Some of her other theories also seem speculative, such as when she argues that we tend to help people with fearful faces because the expression makes them look more babyish. Then there is her idea that the evolution of lactation in mammals is a prerequisite for intensive maternal care. Where does that leave the impressive parenting skills of non-lactating Emperor penguins, Nile crocodiles and even some octopuses?

Still, *The Fear Factor* is a fascinating tour of altruism research, all the better for being sprinkled with anecdotes about Marsh's life, career and unforgettable research subjects. As well as the extremes of human nature, Marsh says plenty that is of relevance to those of us in the middle of the bell curve, including how we can strive to be more altruistic in our everyday lives. ■



Psychopaths score badly when asked to identify fearful faces

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EDITOR'S PICK

What information would an artificial physicist produce?



From Rachael Padman,
Cambridge, UK

John Pavlus asks whether the success of neural networks leaves anything for human physicists (28 October, p 36). It depends on what you think physicists are trying to do. Experiments carried out using the neural networks he describes are great for telling you

how a system is going to work, and potentially for designing new materials. But the only way to have confidence in the results is to test the physical system. A neural network in silicon is just as capable of being misled as are our own carbon-based networks, especially if we fail to provide a piece of relevant information.

The physicist's calling, however, is more than just testing and synthesis. Most of us rate understanding several notches higher. To put physicists out of a job, the neural network needs to explain why it thought the problem was worth solving, which data it regarded as relevant and which irrelevant, what approximations it made, under what conditions the solution is valid, and how the solution fits with the existing corpus of knowledge. Even then, without a

human physicist to explain all this to, it all seems a little pointless.

From James Stone,
Sheffield, South Yorkshire, UK

Pavlus states that computers "represent information in 'bits' that can only have a value of 1 or 0". But a bit of information is fundamentally different from a bit of data.

Each binary digit (bit) of data can have a value of 1 or 0, and each value can represent between 0 and infinity bits of information. For those who want detail: if the probability that a data bit equals 1 is P , then the amount of information represented by a 1 is $\log_2(1/P)$ bits. This value approaches infinity as P approaches zero. It has been proposed to name the unit of information after the inventor of information theory, Claude Shannon.

Body cameras assist both police and public

From James Barber,
London, UK

Alice Klein asks whether body cameras are working to defuse tense situations (21 October, p 22). The evidence seems clear that body cams do make a significant difference in reducing citizens' complaints and violence against police officers.

Police forces thus have a clear duty of care to both their officers and citizens. How long will it be before forces are prosecuted for not giving officers what should now be basic protective kit?

From Keith Meehan,
Los Gatos, California, US

The finding that police use of force and citizen complaints both declined dramatically after body-worn cameras were deployed

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“At this point in the movie, we get that feeling things won’t end well for the humanoids”

Whimsy (aka Shirin) is not entirely convinced that if driverless cars can save lives, so can armed machines (11 November, p 22)

reminded me of a study that found men were more likely to wash their hands after using the toilet if there were other men in the room than if they were alone. Observation seems to elicit best behaviour on so many levels.

From Ben Haller, Ithaca, New York, US

You write that, “eventually, events not caught on camera could be treated as if they didn’t happen, like the proverbial tree falling in the forest” (21 October, p 3). Ask any black man, at least in the US, and they will tell you about being stopped, frisked and harassed – or beaten and imprisoned – by police without cause or due process.

Charges against police of false arrest, perjury, planting evidence, assault and murder are routinely dropped because the court system almost always believes the word of the officer over the word of the

black man. Indeed, since prosecutors know what side their bread is buttered on, charges are rarely brought against officers.

To address these issues, body cams worn by police need to always be on except when permission to disable them is explicitly granted by the police dispatcher for reasons that are in the public record. And their footage needs to be publicly accessible so the police can’t suppress damning incidents.

Luther’s legacy was one of diversity of thought

From Martin Walker, London, UK

Martin Luther’s legacy was arguably not a scientific revolution based on freedom of thought or on rationalism, but the unintentional opening of the door to diversity of thought

(28 October, p 32). Many early strands of Protestantism were highly intolerant of dissent, worse in many cases than the Catholic church. But by placing the Bible rather than the church hierarchy at the centre of truth, Protestants reopened Christianity to a diversity of beliefs – often conflicting with each other.

For the previous millennium, the church hierarchy had tried to put in place a consistent belief system on top of a holy book that is highly inconsistent in both beliefs and narratives. The Reformation made it close to impossible to re-establish conformity and exposed many biblical teachings to direct conflict with the reality of the world.

The scientific revolution may have started independently of the Reformation, but the diversity of thought it unintentionally created allowed it to flourish.

From Andrew Whiteley, Consett, County Durham, UK
Philip Ball’s perceptive article on science and the Reformation was most refreshing. In England, particularly, the work of medieval figures such as Robert Grosseteste and Roger Bacon, not to mention that of Muslim scholars, demonstrated a real desire to come to a properly scientific, empirical understanding of the world. After all, the theistic vision of the universe as the offspring of a supremely rational creator is, to say the least, wholly consistent with the scientific enterprise.

From Peter Basford, Potters Bar, Hertfordshire, UK
Ball says that Nicolaus Copernicus challenged accepted Earth-centred cosmology, but drew little objection from the church, unlike Galileo later, who he blames for provoking it. It has been

“There is a time for many words, and there is also a time for sleep.”

HOMER, THE ODYSSEY

Written by
Wallace Mendelson
MD, former director
of the Sleep Research
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suggested that it was Andreas Osiander's preface to Copernicus's book that allowed him to avoid strong church reaction.

This presented the new system as a familiar academic exercise in mathematical equivalence, not as reality. And because Copernicus used only perfect circles for orbits, he had to approximate the observed celestial movements by adding exactly the same kind of circles on the circumference of the main circle that the accepted Ptolemaic system used.

The ethics of DNA testers putting genes on sale

From Georgia Dempster, Melbourne, Australia
Jessica Hamzelou discusses companies that sell DNA tests to consumers almost as a sideline, the real value being in the data they gather (7 October, p 22). This practice is held to be ethical, so long as consumers have given informed consent.

It is argued that the potential health benefits to the public outweigh the potential risks. But should DNA companies offer their

customers access to genetic counselling services, so that results can be discussed and responsible education about genetic information delivered? Perhaps they could undertake more partnerships with non-profit research organisations to make sure the benefits of the DNA databanks are a public good, not just a commercial one? They could also reinvest some of their profits into non-profit genetic-based disease research.

Moderate meat eating or suppress methane?

From Constance Lever-Tracy, Adelaide, South Australia
Bob Holmes's summary advice for a healthy and environmentally friendly diet was straightforward and helpful (23 September, p 35). Unfortunately, it mentioned only in passing the contribution to global warming of methane burped by cattle and sheep. Some estimate that these ruminants produce up to 20 per cent of all greenhouse gases emitted globally. Pigs and fowl don't produce methane.

When Mark Nearing concludes that "our only rational course of action" is "moderation in our meat consumption (or its elimination)" he ignores this huge distinction between different kinds of meat (Letters, 21 October).

Furthermore, research at James Cook University in Queensland, Australia, is finding that adding the seaweed *Asparagopsis taxiformis* to make up 2 per cent of ruminants' feed completely inhibits methane production.

Remembering William Penney differently

From Jock Webb, Narromine, New South Wales, Australia
Readers from Australia may have a different view of the status of William Penney (14 October, p 42). Undoubtedly, he was an excellent practitioner of nuclear physics, but his work included a number of atomic tests at Maralinga in remote South Australia. These left large areas contaminated and caused significant loss of life among the Aboriginal people, as well as rendering some of their land uninhabitable. The supposed

clean-up by the UK was poor and the long-term consequences for both the Aboriginal people and service personnel have been, some would say, disastrous.

From Peter Urben, Kenilworth, Warwickshire, UK
Fred Pearce says the "Penney dreadful" nuclear weapon "required huge amounts of tritium" and suggests this contributed to the 1957 Windscale reactor fire in the UK. But he also notes that though the nuclear test code-named Orange Herald was announced as a fusion weapon, it wasn't. It may have been a "hybrid", with most of its explosive power coming from fission of uranium and a small amount from fusion of tritium. But in these – and probably in most practical H-bombs – the tritium is mostly generated in situ from lithium.

Now if you're ready, oysters dear...

From Alan Whitworth, Sawston, Cambridgeshire, UK
It is good to know that the tongue-twister "a noisy noise annoys an oyster" is now scientifically proven by the observation that they can "hear" (28 October, p 18).

TOM GAULD



For the record

■ The kinetic energy of an iron asteroid 500 metres across is about a hundred-thousandth the energy Earth receives from the sun in a year (28 October, p 42).

■ Mild-mannered journalists note that the proper name of a certain superhero is Spider-Man, with a hyphen (28 October, p 39).

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What's in a footprint?

OUR planet's astonishing biodiversity is vanishing at a rate 1000 times faster than at any time in history. The populations of many of our most charismatic species, such as the black rhino and Amur tiger, are teetering on the edge. But to halt this catastrophe in its tracks and to protect these species more effectively, we need to know where they are and how many are left. Even for well-known species such as cheetah, there are country-sized gaps in our knowledge.

Many methods of surveying species are expensive, invasive or potentially harmful to the animals. But a solution might be right under our feet: footprints. A footprint is a small and often cryptic repository of valuable data about the animal that made it.

Trackers know footprints like the backs of their hands. WildTrack spent 10 years in various locations in Africa learning from them what's in a footprint. The result is a footprint identification technique (FIT) able to identify the species, individual, sex and age-class of numerous animals just from a digital image of their footprints.

WildTrack was set up as a non-profit organisation that delivers FIT to field projects to help monitor at-risk species. We now have algorithms for more than 15 species over five continents, ranging from rhino to cheetah and polar bear to panda. More recently, we launched a citizen science project called ConservationFIT. Our mission is a bold one: to build the world's first digital database of animal footprints.

We hope that members of the *New Scientist* community will join us in collecting footprint images and developing our user interface. You don't have to be a biologist. If you are a hiker, biker, tracker, forensic scientist, expert web developer, geographer, drone pilot, adventurer or just a keen observer, contact us at info@conservationfit.org.

All you need to participate is a smartphone or camera, a piece of paper, pencil, ruler – and a good eye! **Zoe Jewell, WildTrack**

For more information, visit wildtrack.org

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IN THE jungle, the mighty jungle, the lion sleeps tonight. But who is he sleeping next to? That is the thought troubling Ezekiel Mutua, chief executive of the Kenya Film Classification Board, after the *Nairobi News* reported two maned lions in the Maasai Mara had been spotted in an intimate embrace, raising speculation that Kenya is host to a pair of gay lions.

Mutua – who has been campaigning against depictions of homosexuality since his appointment in 2015, wants action. Previous targets include children's cartoons *Adventure Time* and *Hey Arnold!*, both of which were banned because of their perceived gay subtexts.

Mutua told the *Nairobi News* that the lions needed to be isolated, and if possible, “a PhD study into this bizarre behaviour” carried out. The lions’ actions, he said, could have been learned by observing gay men “behaving badly” within the park, but also through demonic possession. He was certain, however, that it was not through watching films – and

contested that policing the behaviour of lions was beyond the remit of the film board, which is a shame, as we expect many would have rather enjoyed watching him attempt to break up a pair of coital lions.

It’s still not known if the two lions really were both males – females sometimes do grow manes – but such behaviour isn’t unheard of between male lions. Fortunately, with all the problems Kenya’s big cats face, the moral police won’t yet be one of them.

STAYING on the savannah: greater efforts are needed to counter the impact of human activity on the natural world, Prince William has told attendees of the Tusk conservation gala. A growing population “puts wildlife and habitat under enormous pressure” said the prince, who is expecting his third child.

The avid pheasant shooter added “we are going to have to work much harder, and think much deeper, if we are to ensure

that human beings and the other species of animal with which we share this planet can continue to co-exist”.

OUR readers have been mulling over the possible origin of a strange, eight-legged structure pulled out of the surf in Rhode Island (30 September). “The item looks like the remains of a sea anchor,” writes Colin Gordon. “These are used to stabilise a vessel during a storm, preventing it turning broadside and being swamped by heavy seas.” Perhaps it didn’t do what it said on the tin. Has anybody waded in to check for the rest of the ship?

“READING your note concerning the universal smoking ban reminded me of a notice I recently saw at an M6 service station,” says Michael Littlewood. The sign – a familiar sight to British drivers – declares that “Alcohol purchased in this motorway service area cannot be consumed inside or outside the premises.”

Feedback notes that an addendum on the sign reads “Thank you for your co-operation”. A little presumptuous perhaps, as we’re not sure how thirsty travellers could do anything but fail to comply with this message.

PREVIOUSLY we discussed the ins and (mostly) outs of re-gifting a pacemaker (7 October). “In your discussion, you missed the problem attached to cremations,” says Derek Morris. “When my pacemaker was fitted, I was told it would have to be removed because it could explode and damage the kiln.”

Derek says with 30,000 odd pacemakers fitted in the UK every year, there could be money in melting down and recycling the metals within. This is probably also true, Feedback thinks, for more substantial implants like metal hips, and in these austere times, it won’t be long before the government introduces some kind of scrappage scheme for elderly relatives.

WE’VE heard of legal eagles, but canine counsellors is a new one.

The US Louisiana Supreme Court has heard an appeal from a defendant who claims police ignored his request for a lawyer.

According to court documents, Warren Demesme told officers “I know that I didn’t do it, so why don’t you just give me a lawyer dog cause this is not what’s up.”

Under existing law, police can continue an interrogation if the request for a lawyer is stated “ambiguously” – which in this case, would mean that officers believed Demesme was asking for a four-legged attorney. And yet, the court voted 6-1 to deny Demesme’s appeal.

ANY Bluetooth-enabled phone or device may be vulnerable to the BlueBorne cyberattack, Stuart Neilson reads in the latest issue of *Linux Format* magazine. It warns readers that “devices that haven’t been



recently updated could be compromised by an attack from within 32 feet or 9753.6 millimetres.”

“The problem,” says Stuart “is in knowing which way to move that extra 0.1 millimetre when you can’t see from where the cyberattack originates”.

SOME serious calorie counting: Peter Mabey’s latest blood test returns a glucose reading of 5.700000000000002 mMol/L. He says this test has him pegged “down to the very last molecule, and beyond!”

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Harrison Ford hits out: “Today’s greatest threat is not climate change, not pollution, not flood or fire. It’s that we’ve got people in charge of important shit who don’t believe in science”

Rising damp

I work on farms in the fens of East Anglia, UK, where the water table is quite high. Even when there has been rain, the fields seem dry when tides at the coast are low. At high tides, the water seems to rise and make the fields wet. We all know that the moon affects tides at sea, but can it also affect the height of the water table quite far inland?

(Continued)

■ The rising of the water table in East Anglia is not due solely to the gravitational effect of the moon, but also to the intrusion of salt water beneath the subsurface fresh water.

In East Anglia, and other areas near the sea, the fresh water below the surface is in the shape of a lens floating on top of salt water that has seeped into the area. Because seawater is denser than fresh water, an increase in the amount of subsurface seawater has enough hydraulic pressure to push the fresh water upwards. This hydraulic pressure can bring the fresh water to the surface, and in some cases cause significant freshwater run-off.

This effect was discovered independently by W. Badon-Ghyben in 1888 and by A. Herzberg in 1901, and is now known as the Ghyben-Herzberg relation. On small, dry islands, this relationship can be critical, because pumping of the water table is often the easiest way to get fresh water, but it carries the risk of losing the freshwater lens.

Many of these islands have a freshwater lens that could be less than 200 metres thick.

Depletion of the lens has caused problems on small Pacific islands, particularly those without mountains, which often have very little fresh water. Once mechanical pumping became available, people quickly used up the fresh water and ended up pumping up salt water.

How high the seawater rises with pumping depends on the extraction rate, the rate fresh water is replaced, the permeability of the land and how compartmentalised the subsurface is. Some of the Phoenix Islands in the Pacific were abandoned within 10 years of settlement because they ended up with only salt water.

*Stephen M. Johnson
Eugene, Oregon, US*

Absolute hotness

I was reading about the quest for absolute zero temperature in *New Scientist* (18 March, p 10). Is there an equivalent maximum temperature? If so, what is it? And how could one reach it?

■ There is indeed a theoretical maximum temperature – the Planck temperature, or T_P . To understand why, we have to understand the relationship between temperature, energy and wavelength. Simply put, higher temperatures correspond to higher energies, and higher

energies correspond to shorter wavelengths. (We're talking electromagnetic radiation here, because no material object, not even any elementary particle of matter, can exist at anywhere close to the Planck temperature. Photons are all you get.)

So, the maximum possible temperature is the temperature beyond which you can't pack any more energy into a photon. And this is limited by how short a wavelength it is possible for a photon to have. This is limited, in turn, by the smallest possible distance that can be defined in the universe, referred to as the Planck length, which is 10^{-20} of the diameter of a proton. The reason why nothing can be smaller than the Planck length is because at that point, current physical theory breaks down because it is impossible to describe anything beyond T_P without a theoretical understanding of quantum gravity, which we don't have.

This temperature turns out to be about 1.42×10^{32} kelvin.

How could one reach the Planck temperature? It is estimated that the universe was at T_P about 10^{-42} seconds after the big bang. At this time, the entire universe was roughly one-billionth of the diameter of a proton. So, compress the entire universe into a space a billion times smaller than a proton and you'll be more or less there. I advise eye protection and sunblock. Really, really strong sunblock.
*Phil Stracchino
Gilford, New Hampshire, US*

■ Temperature is a measure of the kinetic energy from the random motion of atoms in a material. The fastest speed atoms can move is the speed of light, so this sets an upper limit on the maximum temperature.

However, it is impossible for matter to be accelerated to light speed, so this limit can never be reached. The practical upper limit is the maximum temperature possible before the container a substance is held in melts/sublimes or is blown apart. For solid vessels, the highest melting point recorded is for tantalum hafnium carbide, which has a potential melting point of 4263 kelvin.

But if we do away with solid vessels and use magnetic fields (such as in fusion reactors) instead, then higher temperatures can be reached. Fusion doesn't begin until 15 million °C and many of today's reactors top 100 million °C.

The gravitational fields of the largest stars can constrain materials in their cores estimated to be as hot as 200 million °C and that is probably the highest stable temperature currently in the universe.

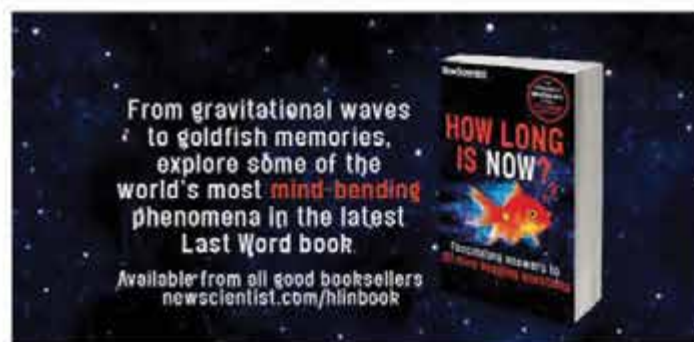
During the collapse of the largest stars into supernovae and black holes, the inside temperatures could reach as high as 100 billion °C. However, it's hard to get inside to check.
*Simon Iveson
Chemical Engineering Discipline
The University of Newcastle
New South Wales, Australia*

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